2K11M1 KRUG-M1
(SA-4B Ganef)
Mobile Medium Range Surface to Air Missile System
Simulator Documentation



Version: 2

Contents



Preface



The KRUG (Circle, in Russian) first truly mobile SAM system was developed by NII-20 under the leadership of V.P. Efremov. It was fully NBC (Nuclear Biological Chemical) protected by filtered over-pressurization system, and was capable of firing only 5 minutes after stopping. It was also the first Soviet SAM system that used the monopulse target tracking method, and had an inbuilt analogue computer. The Soviet Union fielded the first version in 1964. The KRUG was constantly improved during its lifetime, resulting in the KRUG-A, KRUG-M and KRUG-M1 variants. It was never exported beyond the Warsaw Pact states, because of its unique capabilities against western Anti Radiation Missiles (ARMs – Shrike, HARM, etc…), and Tactical Ballistic Missiles (TBMs – Lance, Pluton, etc…). Hungary operated the latest version (KRUG-M1) between 1982 and 2000. Hungarian batteries participated in life firing exercises in 1983, and 1988 at Asuluk in the Soviet Union.

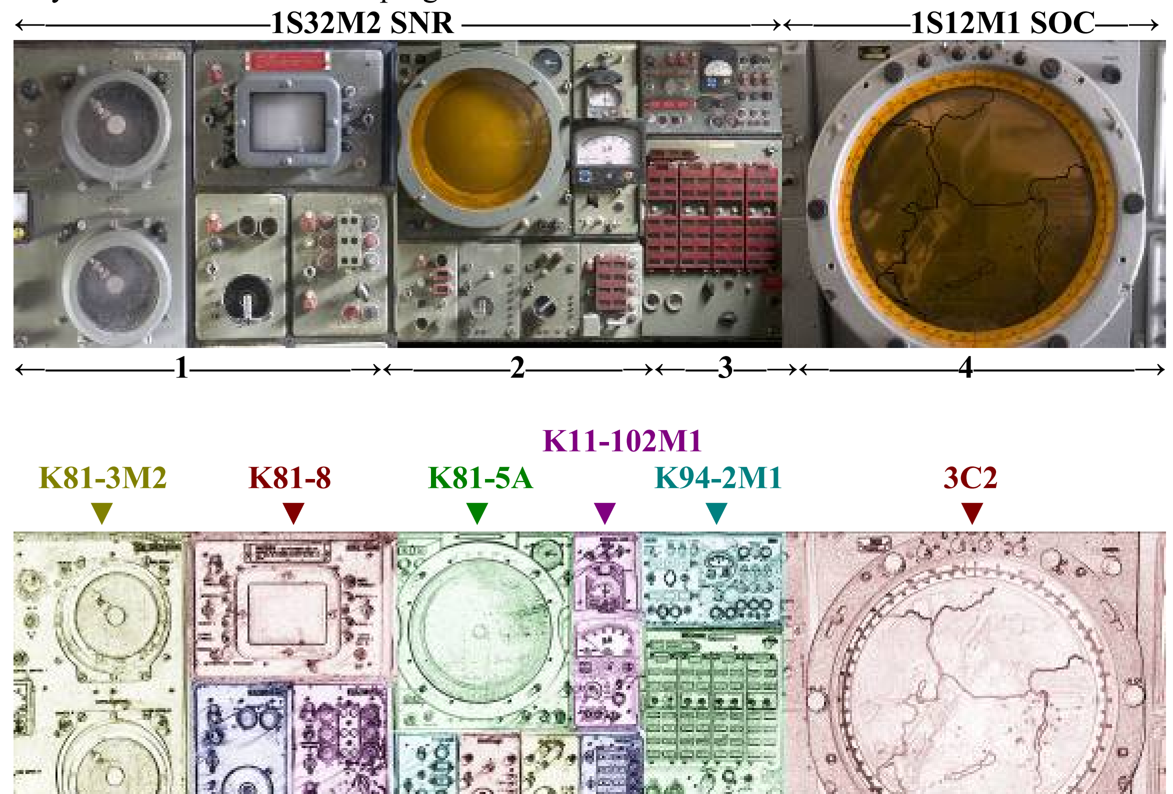
This program simulates the most advanced version, the KRUG-M1, (SA-4B Ganef).

Requirement to run this program

Your computer must be able to display a resolution of 1280x1024 or above.



Keyboard references for the program:



1S32M2 SNR (Pat Hand) Fire Control Radar Key Reference

1, Push the "Z" button, to select the ***Range Officer***'s instruments
*(***K81-3M2***,* ***K81-8***,* ***K81-10M***,* ***K52-2M***)*

2, Push the "X" button, to select the ***Angle Officer***'s instruments
*(***K81-5A***,* ***K11-102M1***,* ***K04-8M***,* ***K51-11M***,* ***K51-10M1***,* ***K04-9M1***)*

3, Pushing the "X" button also selects the ***Battery Commander***'s instruments
*(***K94-2M1***,* ***K04-1M1***)*

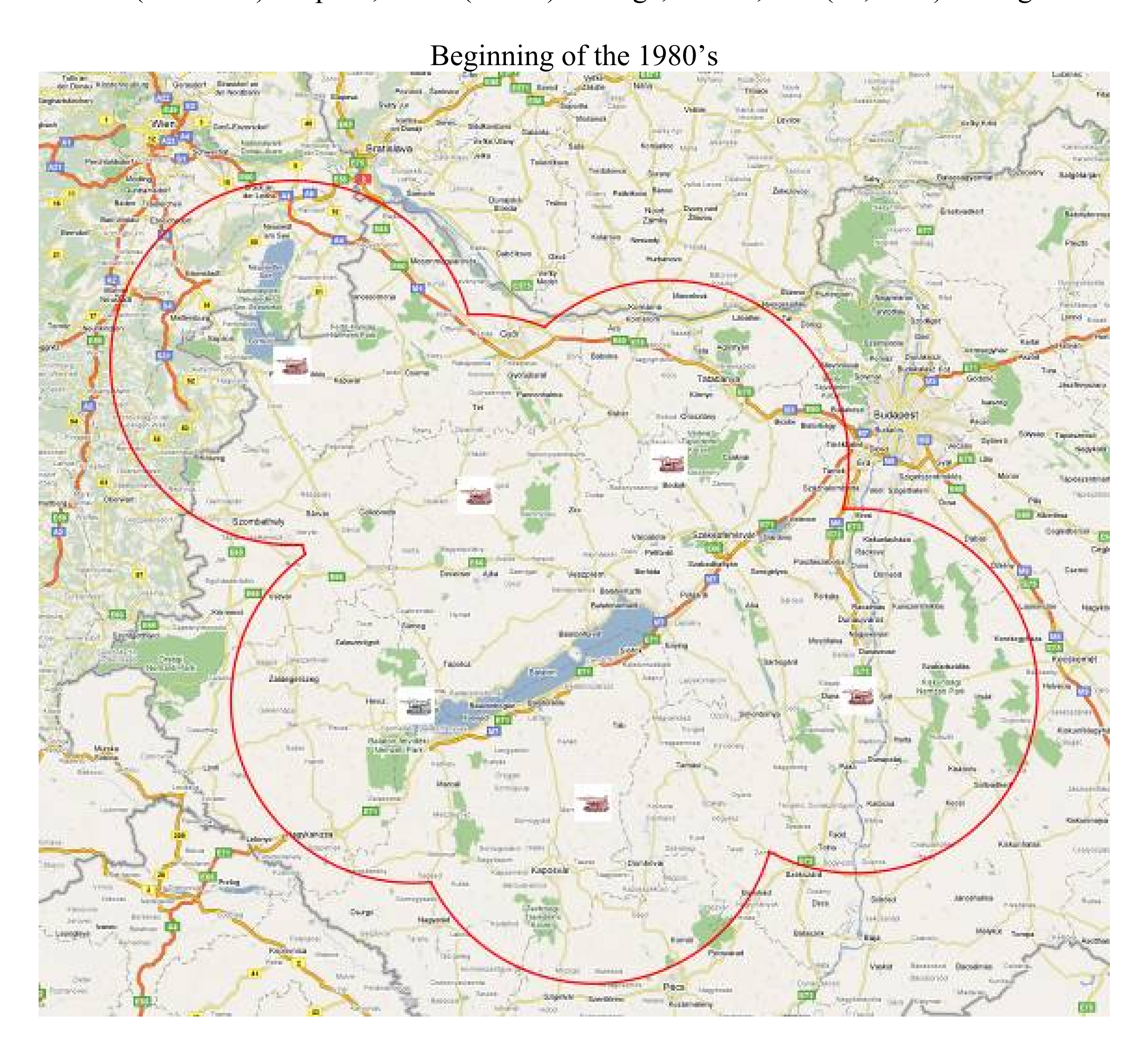
1S12M1 SOC (Long Track) Target Designator Radar Key Reference

4, Push the "C" button, to select the ***Target Designator Officer***'s instrument
*(***3C2***)*

Engagement Zone

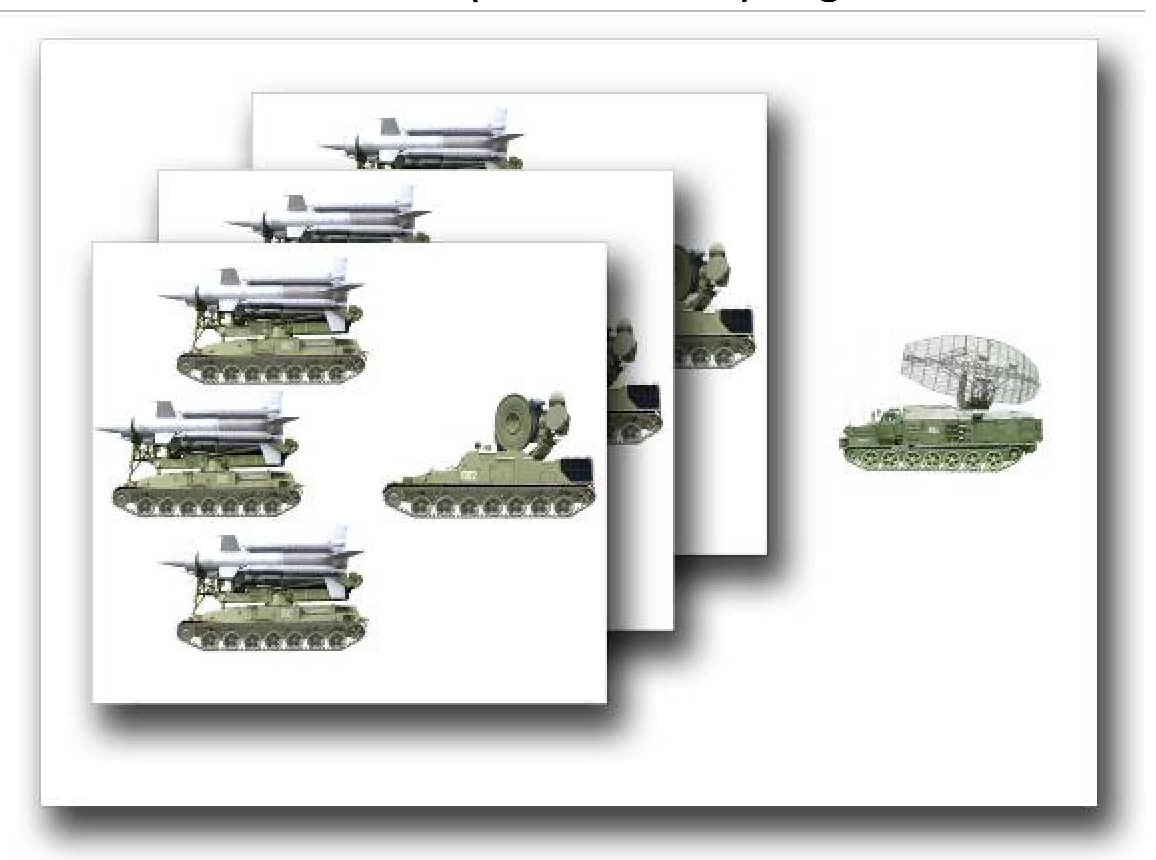
The KRUG-M1 has one target and one missile channel, meaning that it can track one target, and guide one missile onto it. The maximum flight parameters of the target are 800m/s (Mach 2.8) in speed, 50km (27 nm) in range, and 24,5km (81,000ft) in height.

Beginning of the 1980's



At the beginning of the 1980's, two KRUG brigades, and one KRUG regiment were located in the west Hungary.
The Hungarian Army's 7th SAM Regiment was located at Keszthely, with two battalions. The Soviet Army had two brigades, with three battalions each, located at Dunaföldvár, Igal, Mór, Fertőd, and Pápa.

The 2K11M1 KRUG-M1 (SA-4B Ganef) Organization



Each firing battery has:

Three 2P24M1 SPU mobile missile launchers, each transporting two 3M8M3 (Ganef Mod.1) missiles (altogether 6 missiles), and one 1S32M2 SNR (Pat Hand) mobile fire control radar.

Each battalion has:

3 firing batteries and one 1S12M1 SOC (Long Track) target designator radar.

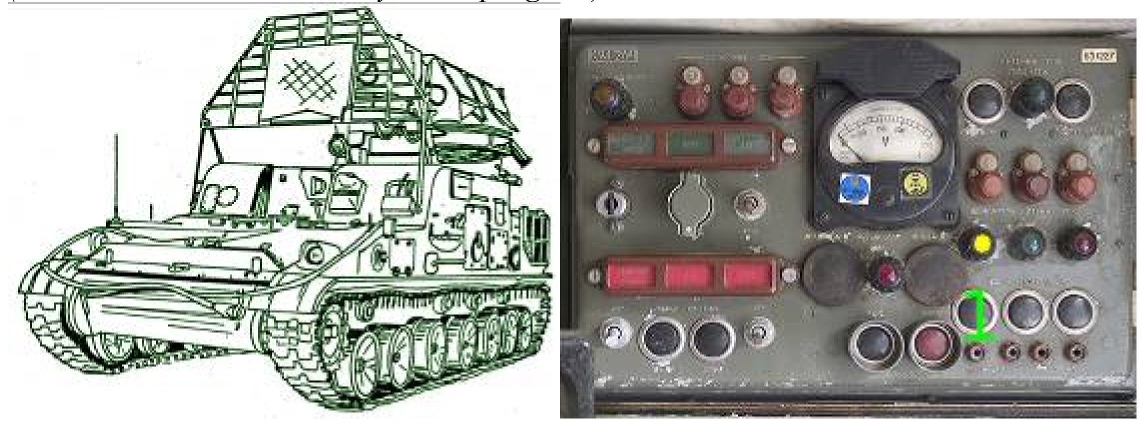
Two battalions form a regiment, while three form a brigade.

Note that SPU is a Russian acronym standing for Self-propelled Launcher while SNR stood for Missile Guidance Station and SOC stood for Target Designation Station.

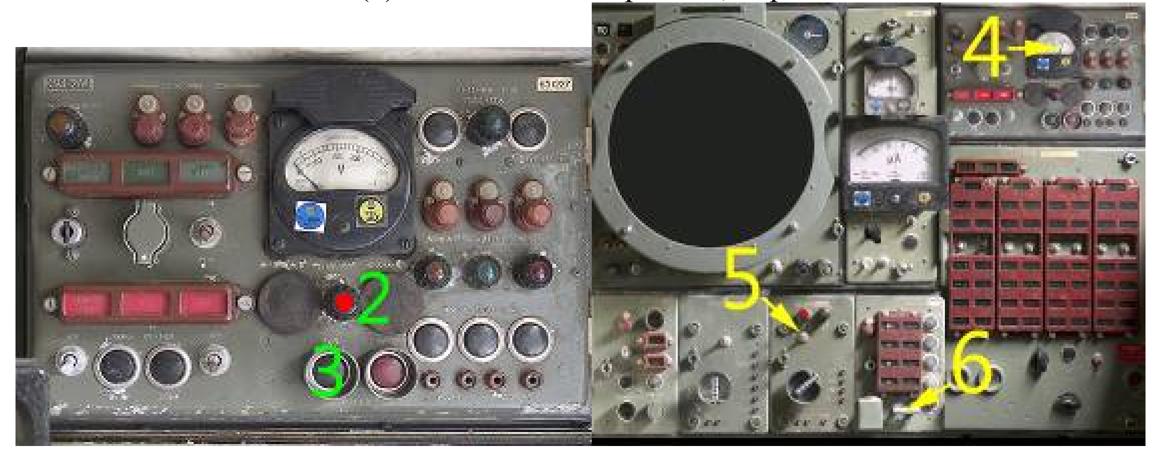
Switching the Simulator On

After stopping from a march, the KRUG antenna tower needed to be deployed from the stowed position.

(Press the "X" button on your keyboard to call up Battery Commander's K94-2M1 panel)
Pressing switch (1) will command the driver of the SNR to start the built-in 1E3M1 gas turbine.
(It will be started immediately in the program)



When the gas turbine reaches its nominal speed, the "generator ready" (2) red lamp will illuminate. The "SNR on" (3) button should be pressed, to power the SNR.



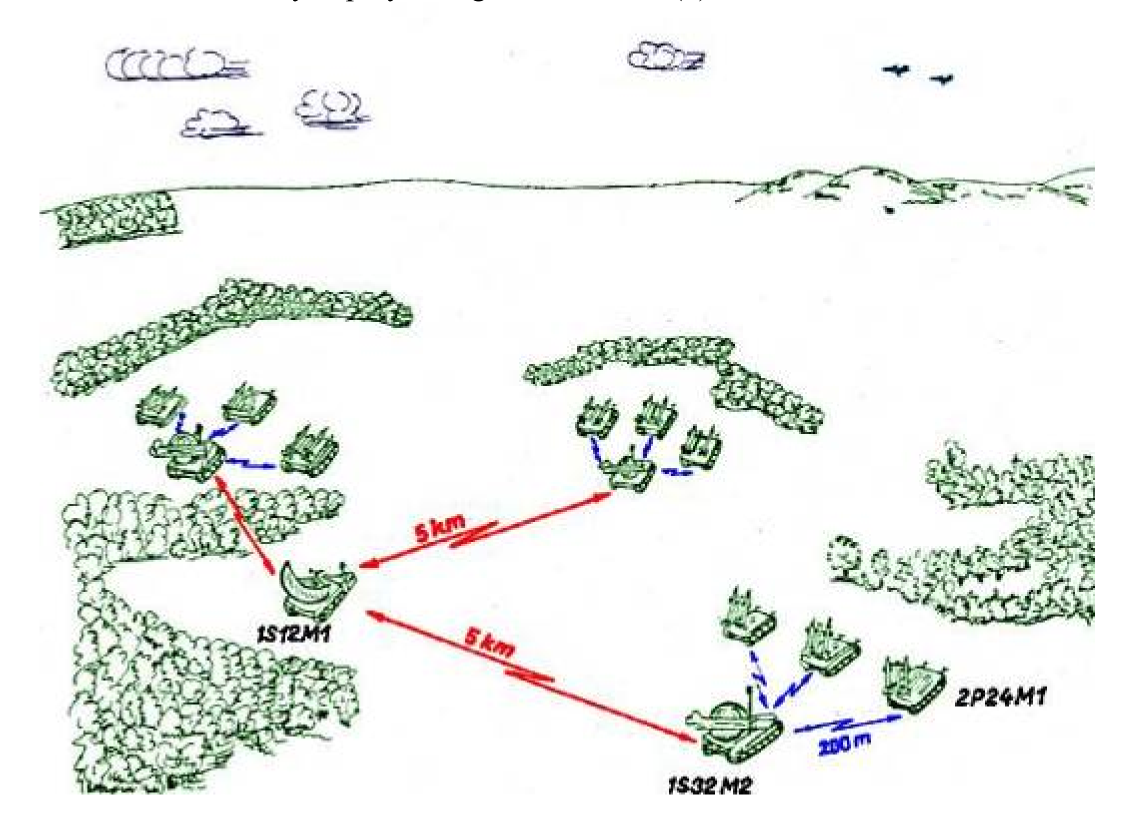
When the required 220 voltage is reached (as read on voltage gauge, 4), the brakes blocking the movement of the antenna tower during a march can be unlocked (by clicking on switch 5), and the antenna tower can be deployed (by clicking on switch 6).

Deploying the Wireless Digital Datalink Antenna

(Press the "X" button on your keyboard to call up Battery Commander's K94-2M1 panel)



The wireless digital data link antenna (7) should be erected by clicking button (8), to have wireless connection with the launchers, and the target designator radar. When the digital data link antenna is fully deployed, a green indicator (9) will illuminate.



The 1S62 (**red**) digital wireless datalink connects the 1S12M1 SOC (target designator radar) to the 1S32M2 SNRs (missile guidance radars) over a maximum range of 5km. The 1S63 (**blue**) digital wireless datalink connects the 1S32M2 SNR (missile guidance radar) to the 2P24M1 SPUs (missile launchers) over a maximum range of 200m. If there is enough time, twisted pair cable can be substituted for the wireless datalink, improving emissions security.

Switching Simulator Off

(Press the “X” button on your keyboard to call up Battery Commander’s K94-2M1 panel)



To switch the SNR off, you need to press the red button (9) on the battery commander’s K94-2M1 instrument.

Methods of Target Acquisition

There are two possible methods of target acquisition:

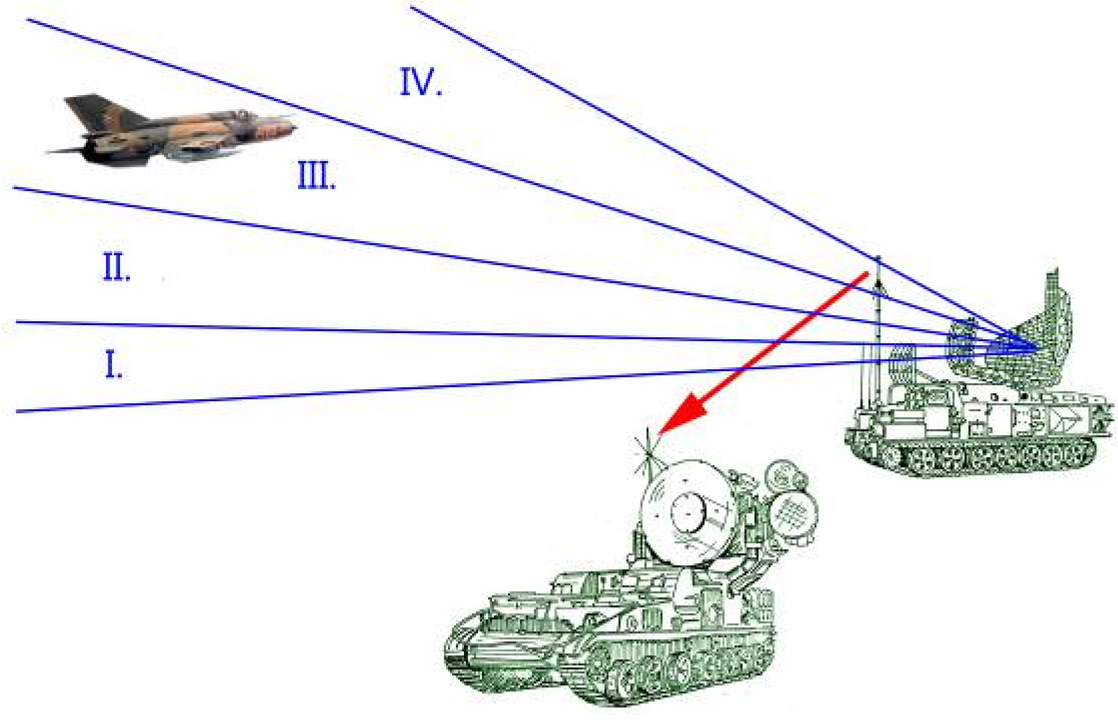
- Primary method is receiving target data from the battery’s 1S12M1 SOC (Long Track) target designator radar.
- Backup method is the manual target search by the 1S32M1 SNR (Pat Hand) fire control radar.

1S12M1 SOC (Long Track) Target Designator Radar

Self contained, mobile decimeter wavelength, 1S12M1 target designator radar.



The mobile UHF band radar has a detection range for fighter sized targets of around 200km. It is connected to the 1S32M2 SNR ("Pat Hand") fire control radar by the 1S62 digital wireless data link, or by cable.

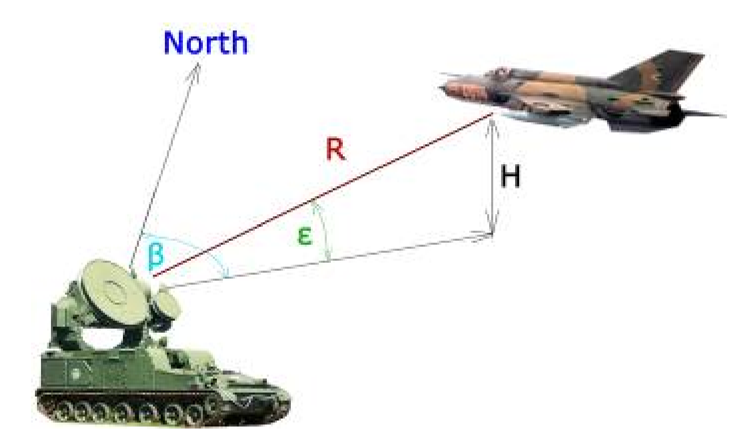


By consecutively scanning four elevation sectors (I., II., III., IV.), the 1S12M1 SOC ("Long Track") target designator radar is capable of acquiring not only the target's range and direction, but also the target's approximate elevation. This can then be passed across the 1S62 wireless digital data link to the 1S32M2 SNR ("Pat Hand") fire control radar.

(Push the "C" button to call up Target Designator Officer's instruments)

1, target at 145°, 112km distance, (lamp yellow - 2) indicates it is in the second elevation zone.

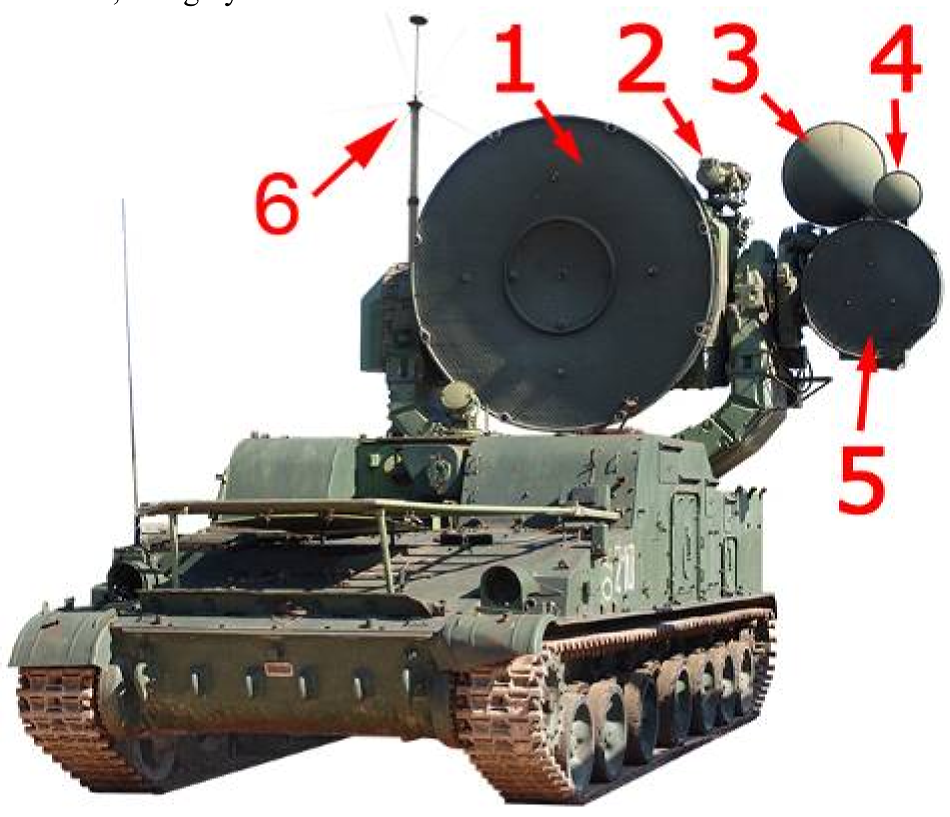
Parametric coordinate system



R – target range
H – target height
ε (epsilon) – elevation angle (antenna up - down)
β (beta) – azimuth angle (antenna left - right)

1S32M2 SNR (Pat Hand) Mobile Fire Control Radar

Built since 1974, Hungary fielded in 1982.



1, AVS-I monopulse target tracking antenna (called "RPC," from the Russian: Radio Locator for Target).
2, TOV camera. (optical target channel)
3, SPK missile command transmitter antenna (called "RPK," Russian acronym for Radio Command Transmitter).
4, AVS-II wide beam missile tracking antenna (receive only).
5, AVS-II narrow beam missile tracking antenna (receive only).
6, retractable antenna of the 1S62 and 1S63 wireless digital data link system.

The Krug (SA-4) was the first Soviet SAM system with independent target (AVS-I) and missile (AVS-II) tracking radars. Because of this, it could guide the missile against the target with larger lead angle, than the earlier eastern systems.

Switching the 1S32M2 SNR (Pat Hand) Transmitter On

(Press the "Z" button on your keyboard to call up Range Officer's K81-10M panel)



When the SNR's antenna system is deployed, the transmitter should be switched on by clicking button (1).
At this stage, it is connected to the dummy load, so it is not radiating to the air, and cannot be detected by enemy's RWR systems.

If a noise jamming target is tracked, the transmitter should be switched off by clicking the red button (2).

The on/off state of the transmitter is indicated by the green lamp (3).



(Press the "X" button on your keyboard to call up Battery Commander's K94-2M1 panel)



Clicking on the RPK switch (4), we send the missile command transmitter's output to the antenna instead of the dummy load. It can be turned on safely, as it will transmit missile guidance commands, only after a missile is launched. When the RPK switch is thrown, the red EKV indication below the switch extinguishes and the green ANT indication above it illuminates.

The RPC (target tracking) system (switch 5), should stay on the dummy load at this stage, to prevent premature discovery of the SNR by enemy's RWR systems.

1S32M2 SNR (Pat Hand) Mode of Operations

(Push the "X" button to call up Angle Officer's K04-9M1 panel)

The indicator of the K04-9M1 shows, where the guidance of the RPC (target tracking



system) is received from.



1..4: **Stowed antenna tower**.
Indicators 1 thru 4 (**βц, Єц, βo, Єo**) are the Antenna Tower Locked lights, β for azimuth, Є for elevation "ц" for Target Tracking (AVS-I) and "o" for Missile Tracking (AVS-II). These lights should have gone out when you deployed the antenna (Page 7).

5, 6: **Manual Target Search** can be selected by clicking on button (6). The "**РУ**" sign (5) is illuminated. The RPC antenna can be rotated manually.

7, 8: **External Target Acquisition** can be selected by clicking on button (8). The "**ЦУ**" sign (7) is illuminated. The RPC antenna is guided by the 1S12M1 SOC target designator radar.

9: **Pelengation**. (Automatic Angle Tracking) "**П**" (9) is illuminated when the RPC (target tracking system) is automatically angle tracking the target. This is also the startup mode of the RPC.

10, **Programmed Target Tracking** "**ПНС**" is illuminated during one of the advanced anti-ARM modes of the SNR. In this mode the RPC is not radiating and the antenna tower is controlled by the built-in SRP (analogue computer) comparing target location data from the 1S12M1 SOC (Long Track).

Rotating the 1S32M2 SNR (Pat Hand)

(Push the "X" button to call up Angle Officer's K51-11M, and K51-10M1 panels)

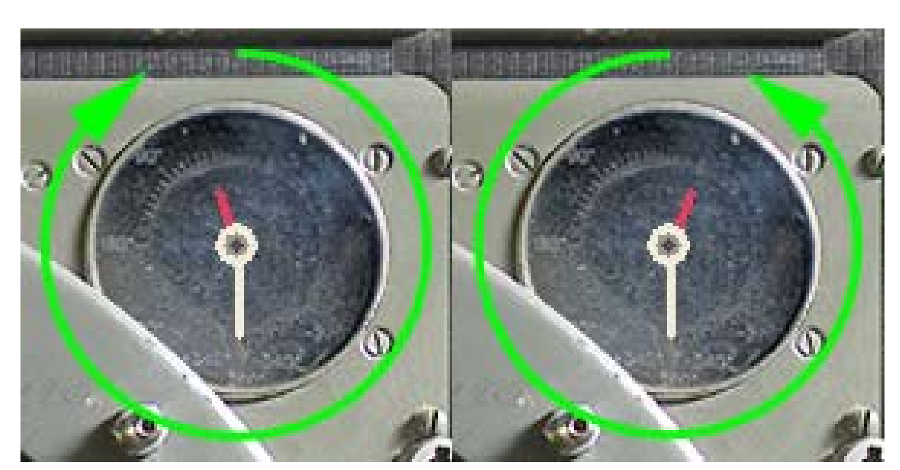


To be able to rotate the controls, first you need to unlock them, by clicking on them with the right mouse button.

The left wheel is for the ε (epsilon - elevation) plane, the right is for the β (beta – azimuth) plane.
Holding down the left mouse button over the wheel, and moving it to right-left, we can rotate the SNR, if we are in "**РУ**", or "**ЦУ**" mode.

1S32M2 SNR (Pat Hand) Restriction on Azimuth Rotation

(Push the "X" button to call up Angle Officer's K81-5A panel)

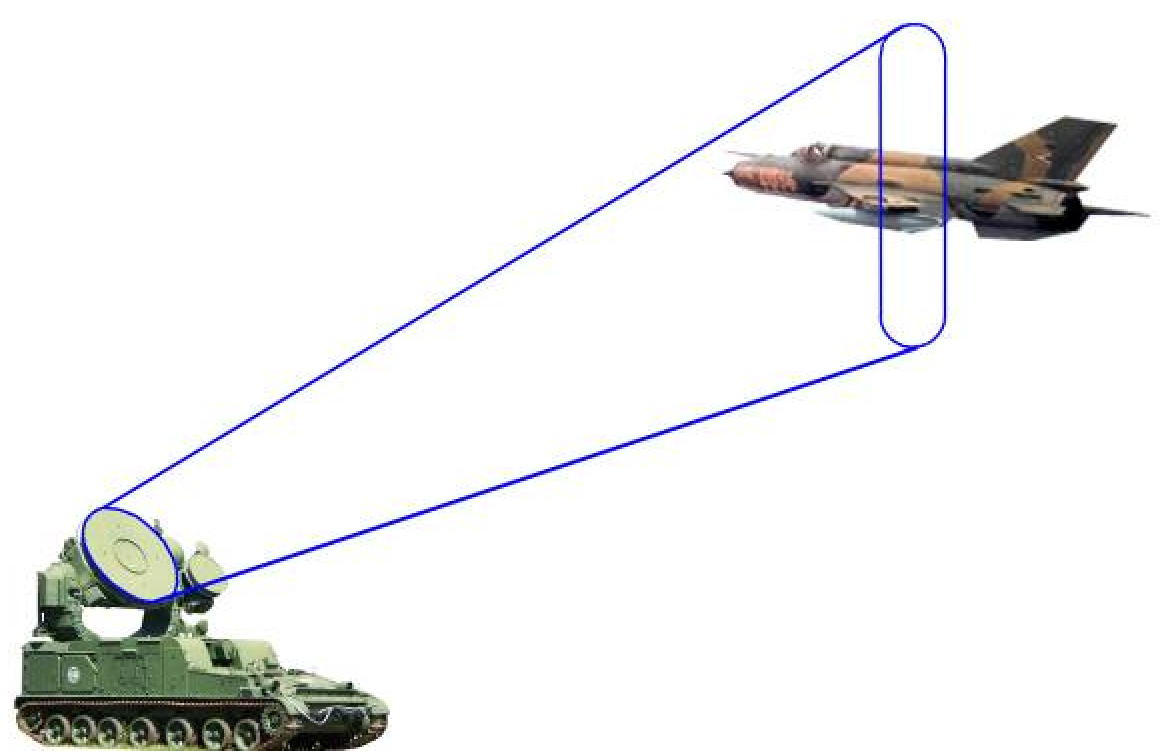


As the antenna tower of the SNR is connected to the hull by a bunch of cables, its rotation is limited. It can only be rotated up to 340° in either direction.

The direction of the antenna tower is indicated by the long white hand. The restricted azimuth is indicated by the short red hand of the instrument. If the antenna tower is rotated beyond the restricted azimuth, indicated by the red hand, the cabling will be damaged. The angle officer must monitor this display to prevent damaging the wiring by over rotation of antenna tower.

1S32M2 SNR (Pat Hand) Target Acquisition

During target acquisition ("**РУ**", or "**ЦУ**" mode), the pencil beam of the AVS-I antenna is scanning an 18° sector, vertically.



The detection range for small fighters (MiG-21, A-4, F-104) is around 70~80km. Maximum indicated detection range is 110km.

1S32M2 (Pat Hand) Target Tracking

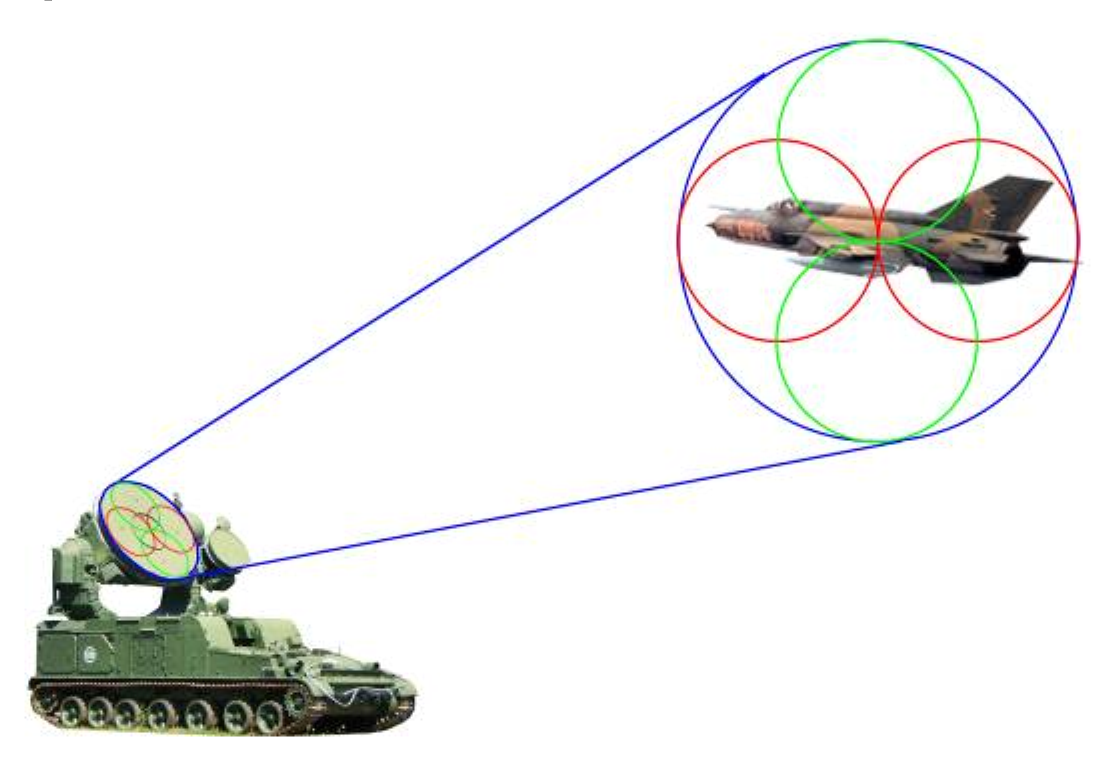
Automatic target tracking ("**П**" mode) is performed with the monopulse mode of the AVS-I (RPC). Older radars measured the radar return from the target and the area around the target. The monopulse target tracking method broke each returning radar pulse into sectors and measured the return across sectors to determine the three coordinates (elevation, azimuth, range) of the target. The name came from the fact that this could be done from a single (mono) radar impulse. This method required significantly shorter transmitting time, compared to the method used by earlier Soviet SAM systems and was more ECM resistant.

Soviet SAM systems using the TWS (Track While Scan) target tracking method only: S-25 Berkut (SA-1 Guild), S-50 Dal (SA-5 Griffon), SA-75 Dvina (SA-2A Guideline), SA-75M Dvina (SA-2B/F Guideline), S-75 Desna (SA-2C Guideline)

Soviet SAM system using both the TWS (Track While Scan) and the LORO (Lobe On Receive Only) target tracking method: S-75M Volhov (SA-2E Guideline)

Soviet SAM system using the LORO (Lobe On Receive Only) target tracking method only: S-125M Neva (SA-3 Goa)

The monopulse signal is emitted by the AVS-I in the (blue) pencil beam. The reflected signal is received by the AVS-I antenna system, splitting it into three beams, (blue, red, green), where two beams are double pencils (red, green). The target tracking system seeks to minimize the signal across the two double pencils and maximize the signal at the blue pencil beam.

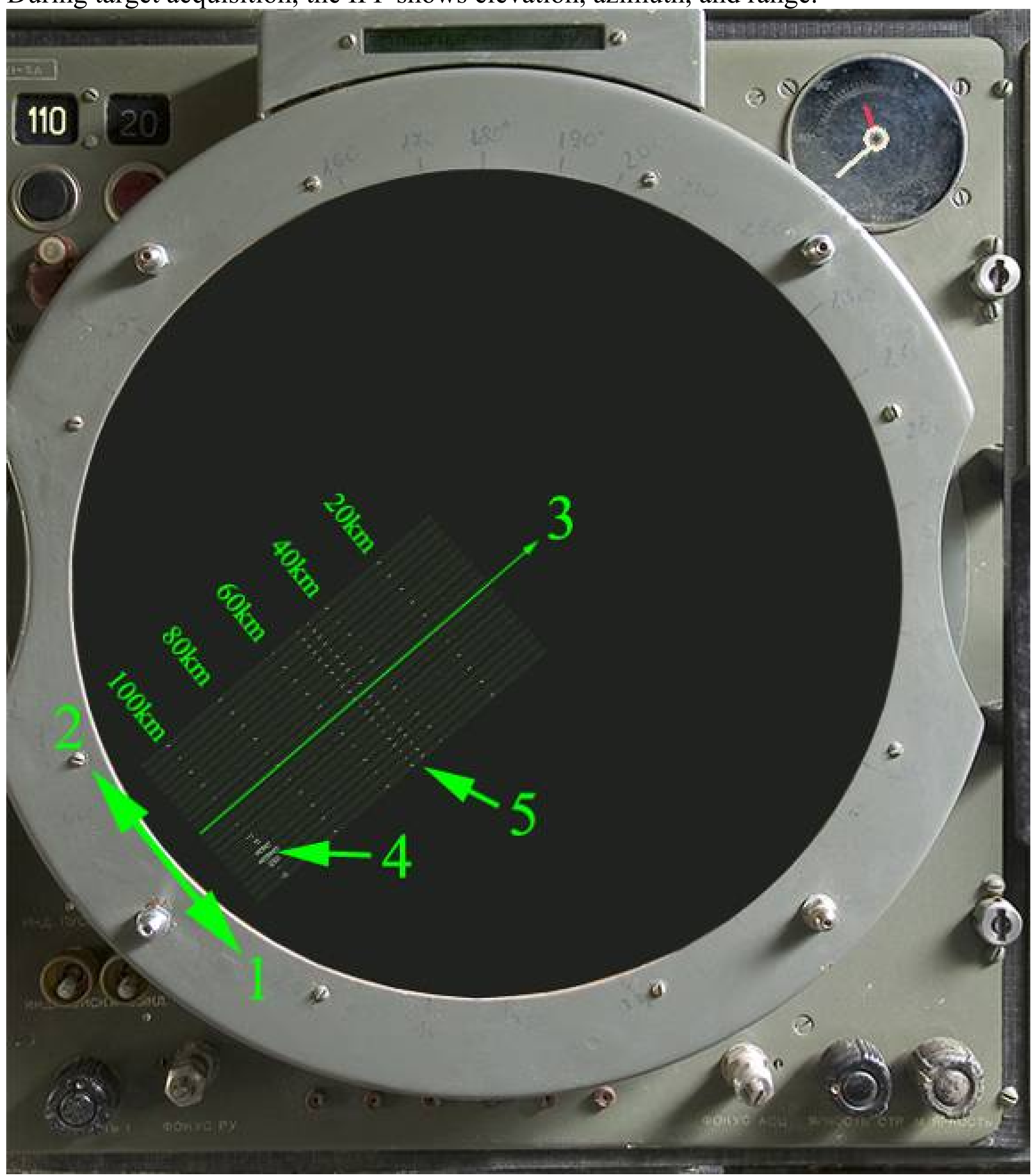


Understanding the Indicators

IPP Three Dimensional Indicator 110km Display

(Push the “X” button to call up Angle Officer’s K81-5A panel)

During target acquisition, the IPP shows elevation, azimuth, and range.

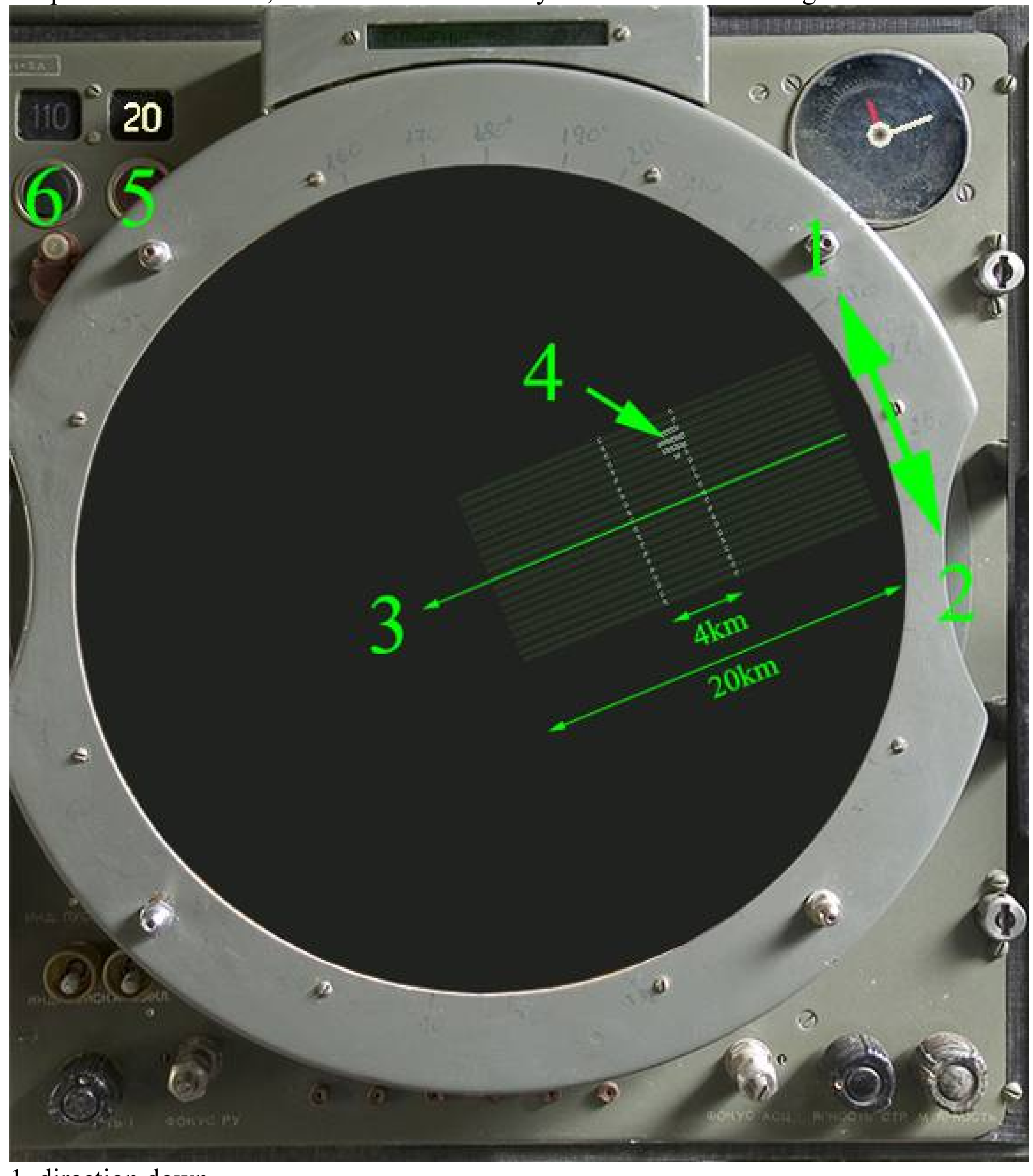


1, direction down
2, direction up
3, boresight
4, target under the boresight, at 230° azimuth, and at 97km range.
5, 4km long selected area at the lower sweep of the Range indicator

IPP Three Dimensional Indicator 20km Display

(Push the “X” button to call up Angle Officer’s K81-5A panel)

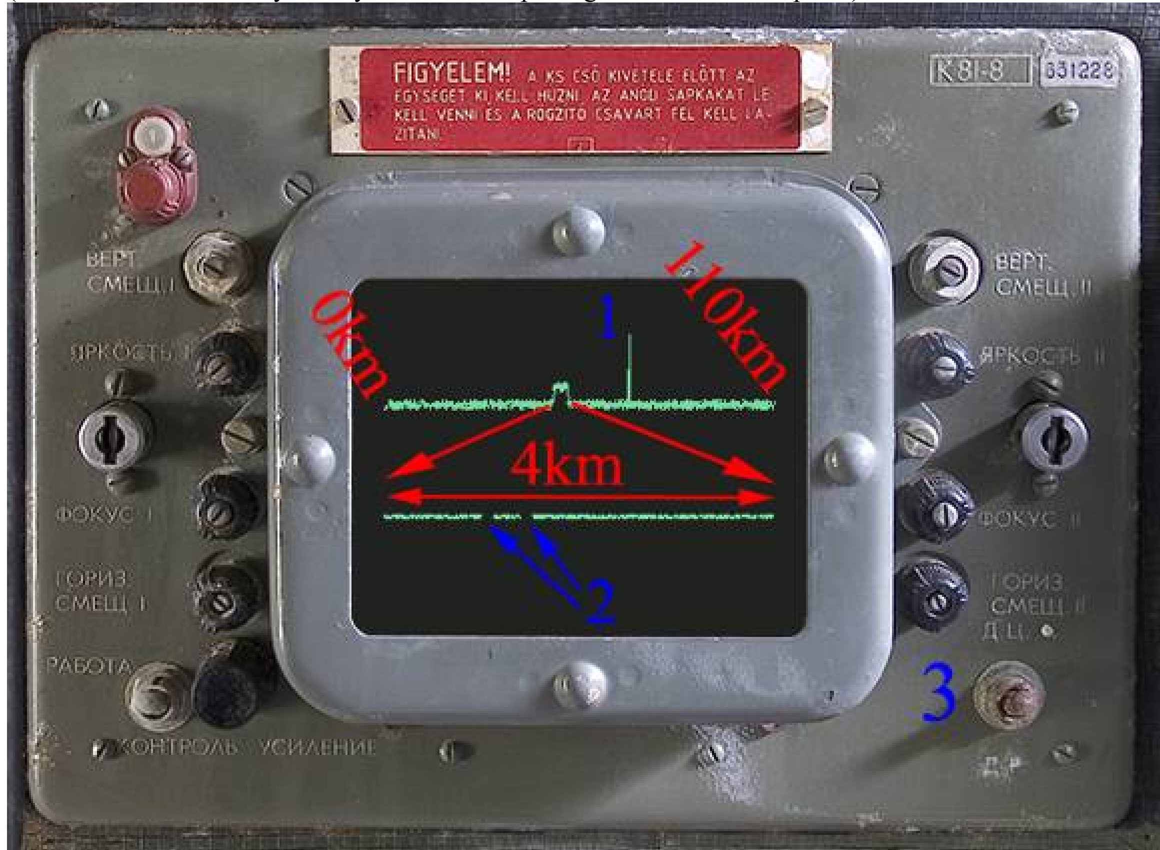
20km area of the target’s range gate area can be selected by pushing the red button (5). 110km can be selected by the black button (6). Note, when “**ЦУ**” External Target Acquisition is selected, the IPP is automatically switched to 20km range mode.



1, direction down
2, direction up
3, boresight
4, target under the boresight, at 70° azimuth.

Range Indicator

(Press the “Z” button on your keyboard to call up Range Officer’s K81-8 panel)



The range indicator has two sweeps. Upper sweep shows the radar’s full range (0km at left, 110km at right); target (1) indicated as a positive spike, missile (4, below) as a negative spike. The lower sweep is the 4km magnification of the upper sweep, containing the range gates (2) of the system. During tracking, with the selector switch (3) we can select what part of the upper sweep we would like to magnify. Upper position “**Д.Ц.**” will show the target range gate, while the lower selection “**Д.Р.**” will show the missile’s range gate in the lower sweep. Examples of the difference:



I. Selector switch is in the “**ДЦ**” position, the target (1) is inside the range gates (2), the missile’s negative spike (4) is visible left of target in the upper sweep.

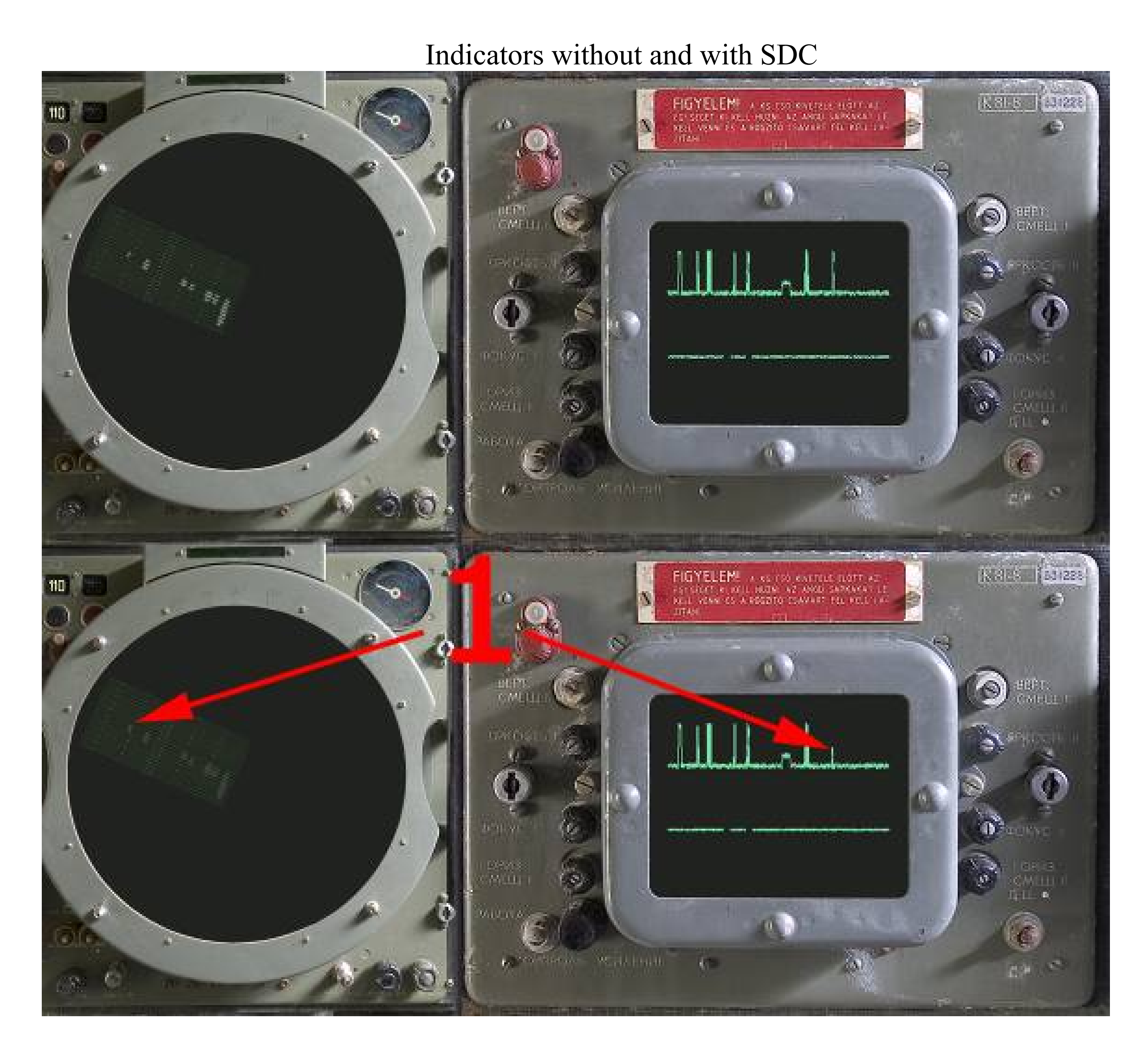
II. The selector switch is in the “**ДР**” position, the missile (4) is inside its range gates. The target’s positive spike (1) is visible in the upper sweep.

III. Just before missile impact, both the target (1), and the missile (4) are visible in both sweeps.

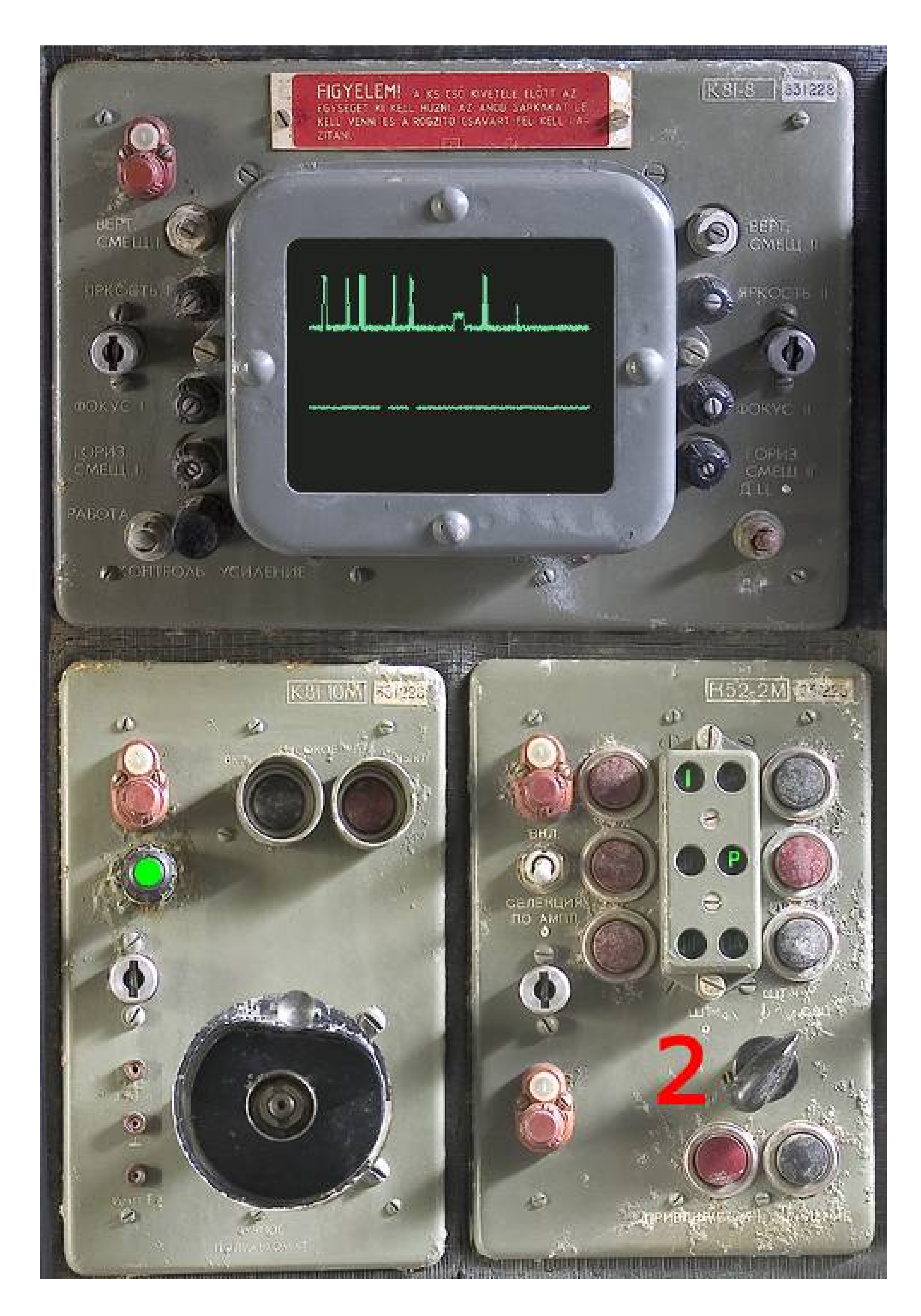
Using the SDC (Moving Target Indicator) to reduce ground clutter

If the target is flying at very low altitude, the ground clutter can make the target acquisition difficult. The SDC using the impulse Doppler mode of the SNR can differentiate between the targets by their radial speed. Important to note, that by the usage of SDC, low radial speed (hovering or parallel flying) targets can completely disappear from the indicator.

Indicators without and with SDC



1. Low flying target in heavy ground clutter, not visible without SDC.

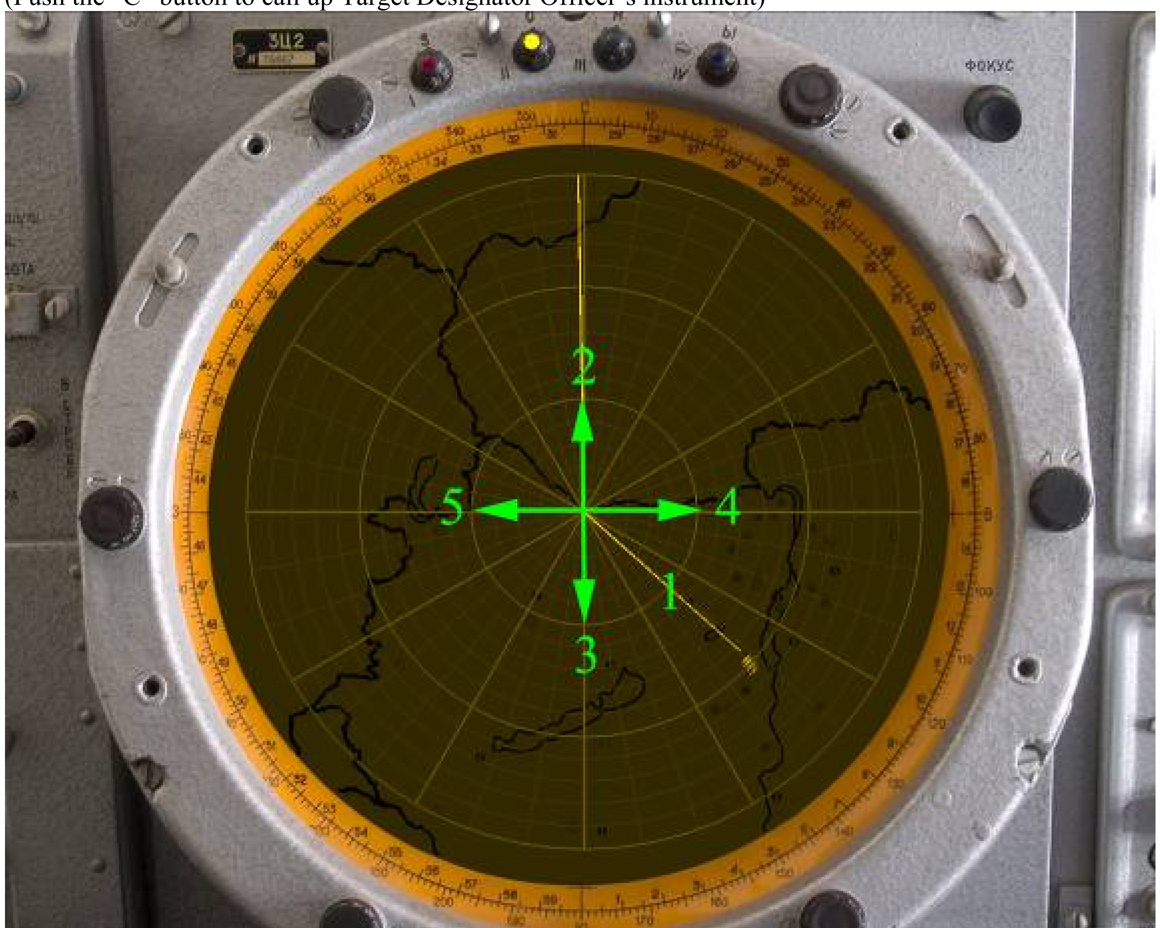


2. SDC mode selector switch settings:
ST-I, left – SDC off
ST-II, middle – not simulated
SDC, right – SDC on

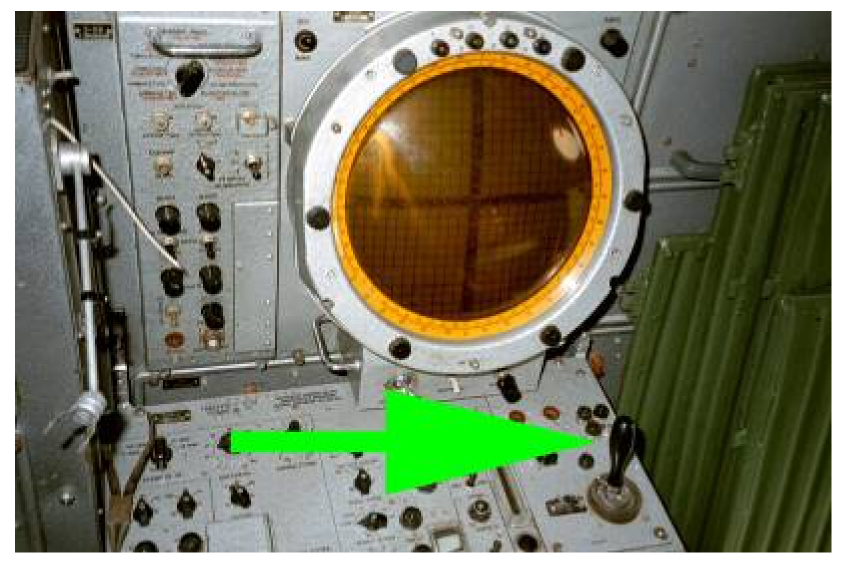
Note, that on the range indicator, the moving target has an amplitude modulated signal.

External Target Acquisition using 1S12M1 SOC (Long Track)

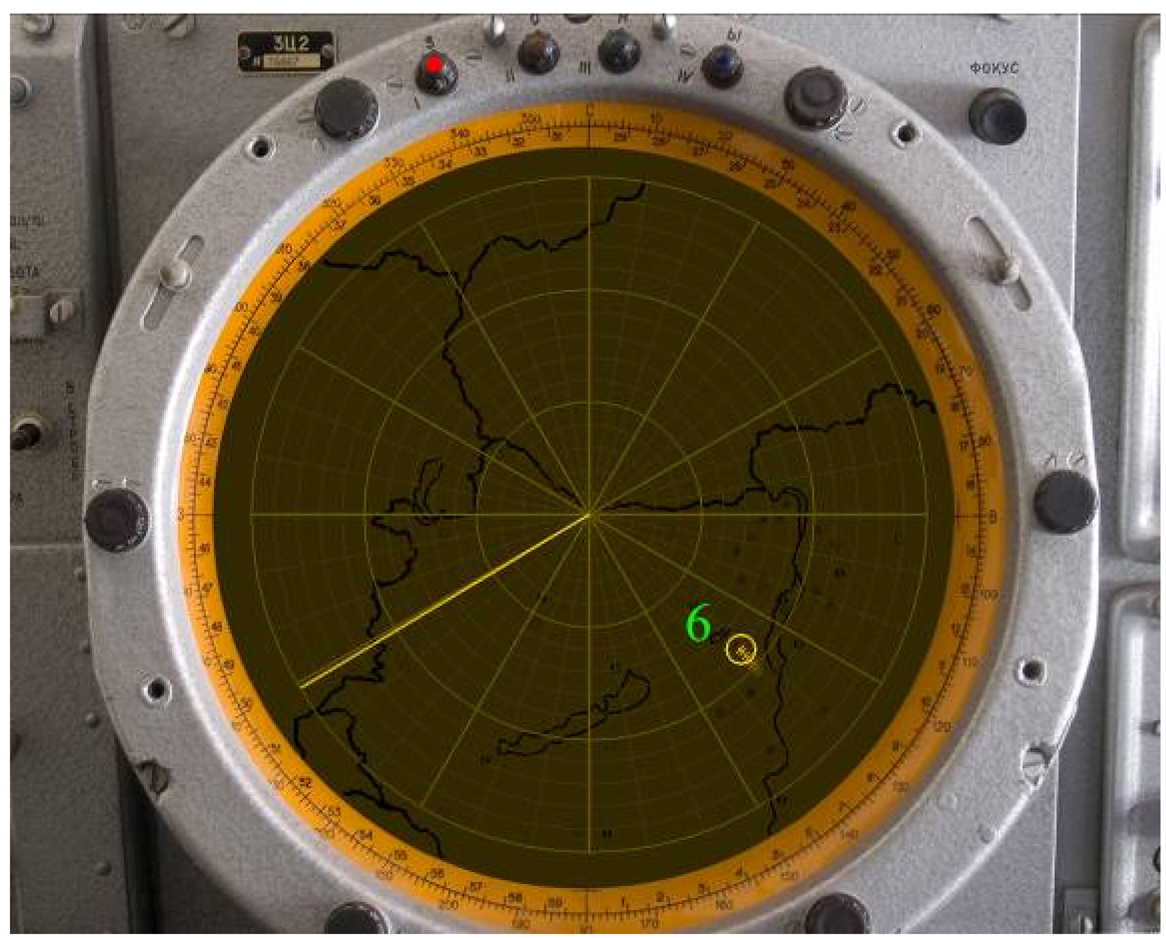
(Push the "C" button to call up Target Designator Officer's instrument)



The target selector line (1) can be moved, by holding down the left mouse button over the indicator and moving it. Moving it up (2) from the center will increase its length, while moving it down (3), will decrease it. Moving it right (4) from the center will rotate its azimuth clockwise, while moving it left (5), will rotate its azimuth counter clockwise.

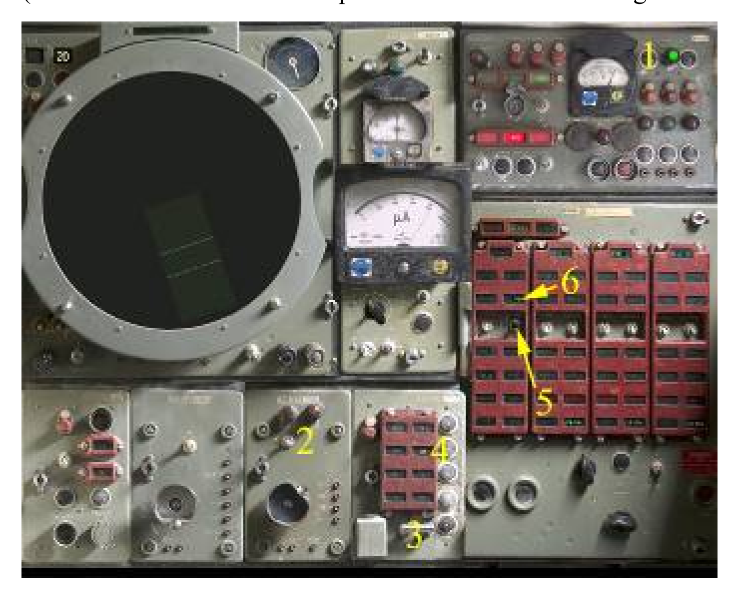


In real life, the movement of the target selector line is done by a joystick.

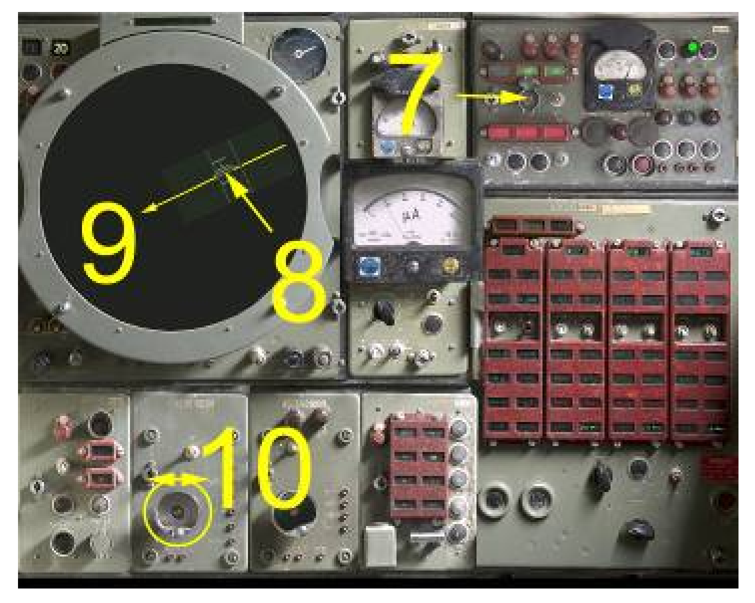


When the target is close enough to the target selector line, it can be designated, by clicking on the indicator, by the right mouse button. If the designation is successful, the target designation line is disappears, and for a short period, the designated target is marked (6) by a circle.

(Push the "X" button to call up the Commander's and Angle Officer's panels)



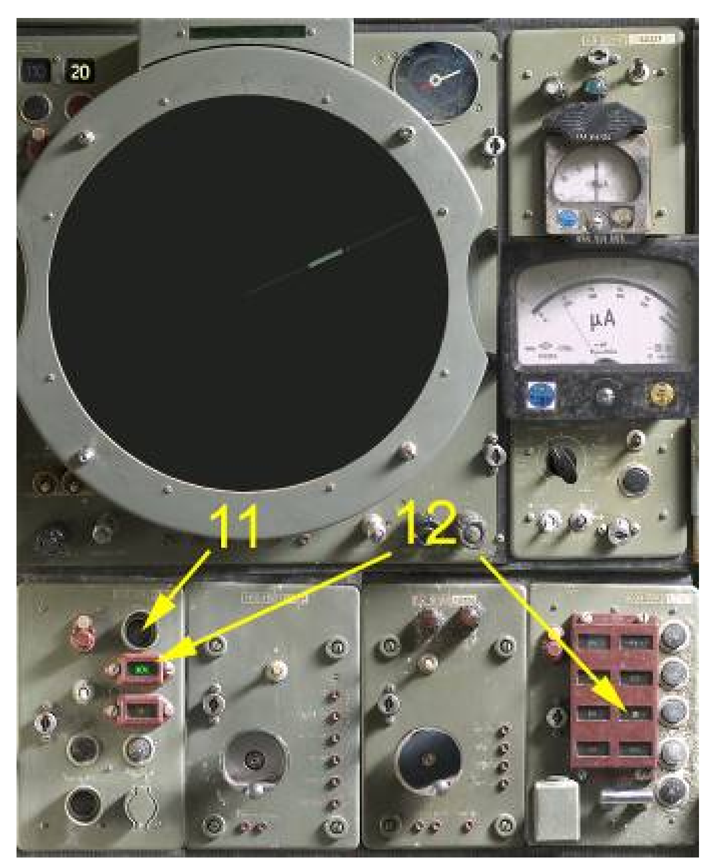
To receive the designated target from the SOC:
1S62 digital wireless datalink antenna should be erected (1).
Antenna tower should be unlocked (2), and deployed (3).
External target designation (4) mode "**ЦУ**" should be selected.
Target designation mode should be selected "Primary" (up - 5).
Receiving external target designation indicator will illuminated (6), and the SNR will rotate towards the designated target.



When the antenna tower is rotated towards the target, and the target is in the rage of the SNR (100km for average sized, and 70~80km for small sized target), the RPC (target tracking) system's transmitter (switch 7) is switched onto the antenna instead of the dummy load, by double clicking on it with the right mouse button. When the guarded RPC switch is thrown, the red EKV indication below the switch extinguishes and the green ANT indication above it illuminates, indicating, that the enemy's RWR systems can locate the SNR from now…

… from this moment, prowling Wild Weasel pilots will start to prepare their AGM-88 HARM missiles to be launched against us, so we need to be quick!!!

If the target (8) is off the bore sight (9), then the RPC's elevation should be corrected, by rotating the elevation wheel (10). (Holding down the left mouse button over the wheel, and moving it to right-left.)

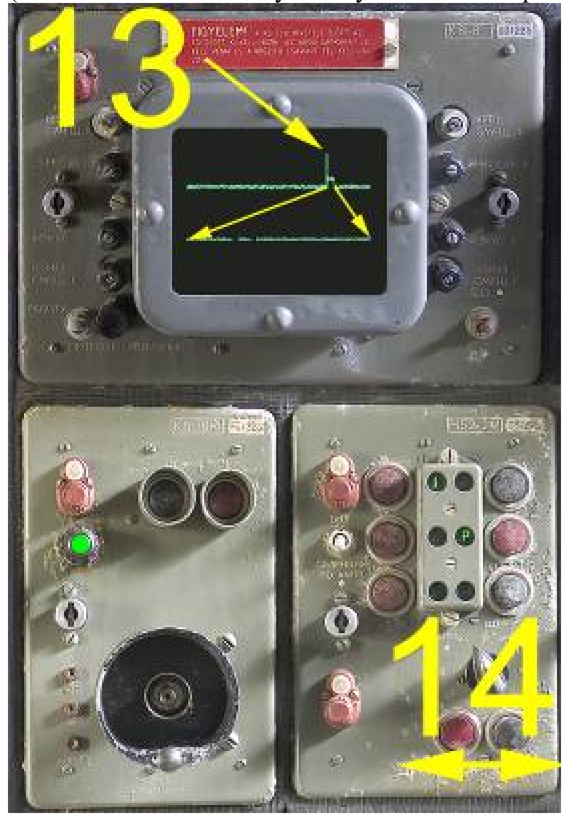


When the target is touching the bore sight, the RPC (target tracking system) could be switched into the "**АСЦ**" (Automatic Angle Tracking) mode, by clicking on the ASC button (11).

If the transition was successful, the "**АСЦ** ", and the "**П**" (12) indicator will illuminates.

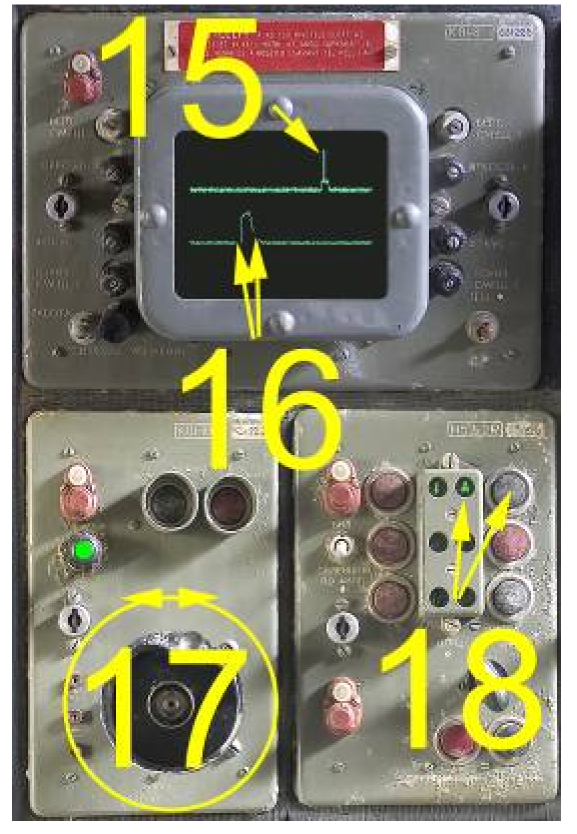
From now, the AVS-I (RPC) system is automatically angle tracking the target, by illuminating it with the monopulse method.

(Press the “Z” button on your keyboard to call up Range Officer’s panels)



The target (positive spike - 13) should be moved into the lower range sweep of the 4km magnified area of the range gate, by pushing the range buttons.

14, Pushing, and holding down the red button is moving the range gate closer (left), while pushing and holding down the black button is moving the range gate further (right).

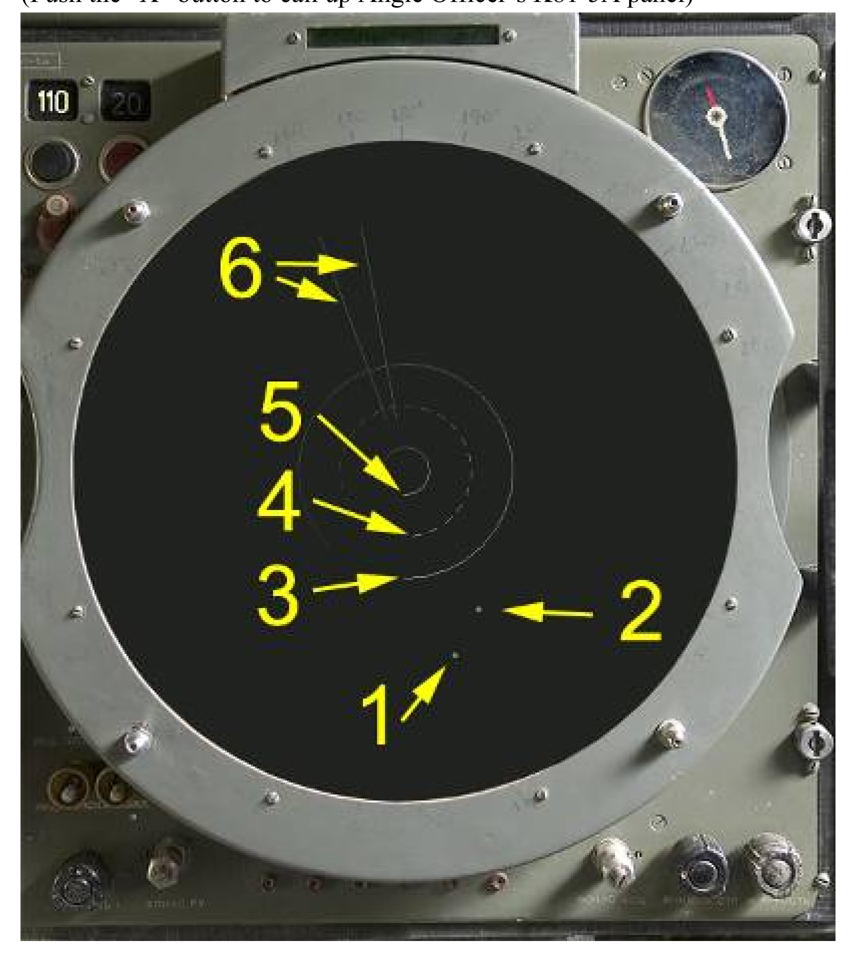


15, When the targets positive spike is moved inside of the 4km magnified area of the lower sweep, it should be moved between of the two range gate (16), by rotating the range wheel (17). (Holding down the left mouse button over the wheel, and moving it to right-left.)

18, When the target is inside of the range gate, we can switch the system into full automatic tracking, by clicking on the “**A**” button (18). If the transition was successful, the “**A**“ indicator (18) will illuminates, and the SNR will switch into Full Automatic Monopulse Tracking of the target.

IPP Three Dimensional Indicator Launch Mode Display

During target tracking, the IPP indicator switches to launch mode.
This rotating screen is generated by the SRP (analogue computer).
(Push the "X" button to call up Angle Officer's K81-5A panel)



1, the target is indicated by a dot.

2, the calculated theoretical missile-target impact point is also indicated by a dot.

3, Missile's maximum range is indicated by the outer solid ring.

4, Missile's ideal range against maneuvering targets is indicated by the dashed ring.

5, Missile's minimum range is indicated by the inner solid ring.

6, Forbidden launch zone borders are indicated by two lines.

Deciding the target tracking method.

As the launch of ARM (Anti Radiation Missile) is expected against any transmitting SNR, we should switch it into one of its anti-ARM mode, to make the Weasel's job harder.

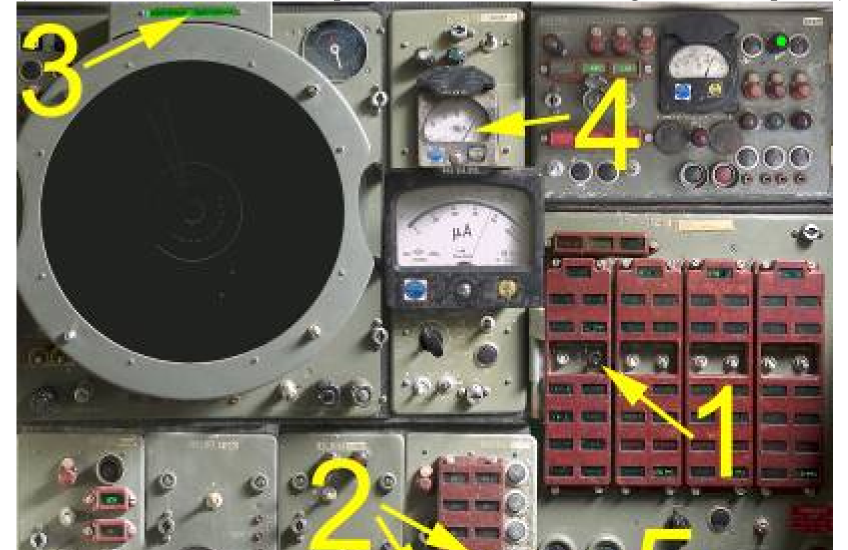
If the calculated theoretical missile-target impact point (2) is outside of the missile's maximum range (3 - outer solid ring), **"ПНС" PNS (Programmed Target Tracking)** mode should be selected.

If the calculated theoretical missile-target impact point (2) is inside of the missile's maximum range (3 - outer solid ring), **"ПИ" PI (Periodical Illumination)** mode should be selected.

“ПНС” (PNS) Programmed Target Tracking Mode

During the Programmed Target Tracking Mode, the SNR is off the air, cannot be detected by the enemy RWR (Radar Warning Receivers), and cannot be shot at with ARM (Anti-Radiation Missile, for example AGM-88 HARM).
The SNR is silently (without electronic emission) following the predicted path of the target using the data from the SRP (onboard analogue computer), and comparing it with the true path of the target, measured by the SOC.
If the difference of the predicted and measured target path is grown over 7km, the SNR is illuminates it, for a short true target path update, then switches off again.

(Push the “X” button to call up the Commander’s and Angle Officer’s panels)



1, Before switching to the PNS Mode, the External Target designation mode should be selected “Continuous” instead of “Primary”, by double clicking on the selector switch with the left mouse button.
2, By clicking on the PNS button (in reality it should be pressed for the whole time by the Angle Officer), the “ПНС” indication will be illuminated, instead of the “П”.
3, As the SNR is off the air, it is safe from the enemy’s Anti-Radiation Missiles, the “ИЗЛУЧЕНИЕ ВЫКЛЮЧЕНА” (Radiation Off) indication is illuminated.
4, The “ПНС20км” instrument is indicating the difference between the predicted, and actual target path.
5, If the indicated difference is larger then 7km, we need to renew the targets predicted path, by shortly illuminating it with the SNR, by pressing the “ПНС- ПА” button.

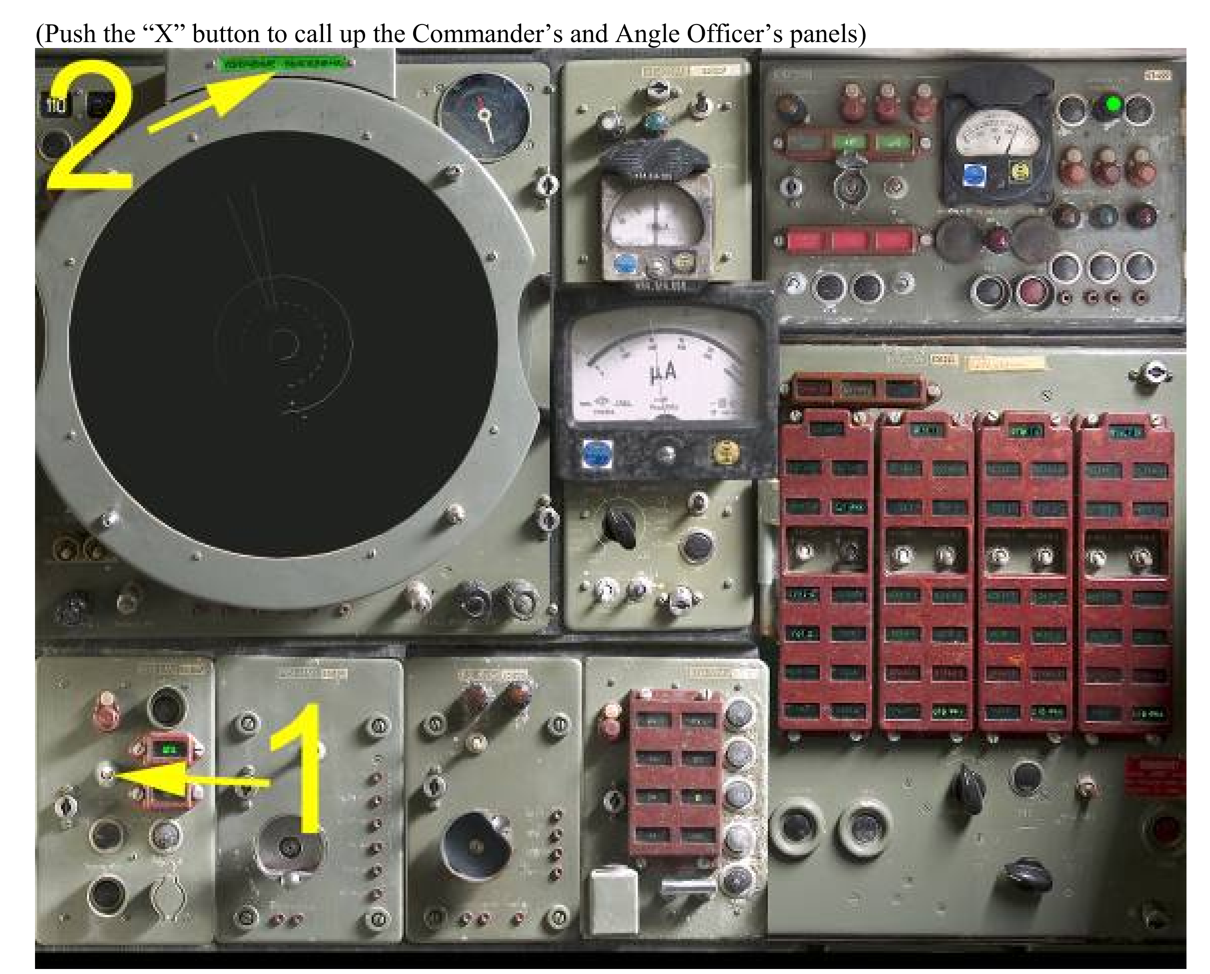
If the calculated theoretical missile-target impact point is reached the missile’s maximum range, the “ПНС” Programmed Target Tracking Mode should be switched off by clicking on the PNS button (2) again (in reality it is released by the Angle Officer), and the “ПИ” PI (Periodical Illumination) mode should be selected instead of.

“ПИ” (PI) Periodical Illumination Tracking Mode

During the Periodical Illumination Target Tracking Mode, the SNR is silent for a period calculated by the SRP (onboard analogue computer), and on the air (to update the target’s path) only the shortest required time by the monopulse method (around only 1 second).

While the SNR is silent, it cannot be detected by the enemy’s RWR (Radar Warning Receivers), and cannot be shot at with ARM (Anti-Radiation Missile, for example AGM-88 HARM).

(Push the “X” button to call up the Commander’s and Angle Officer’s panels)

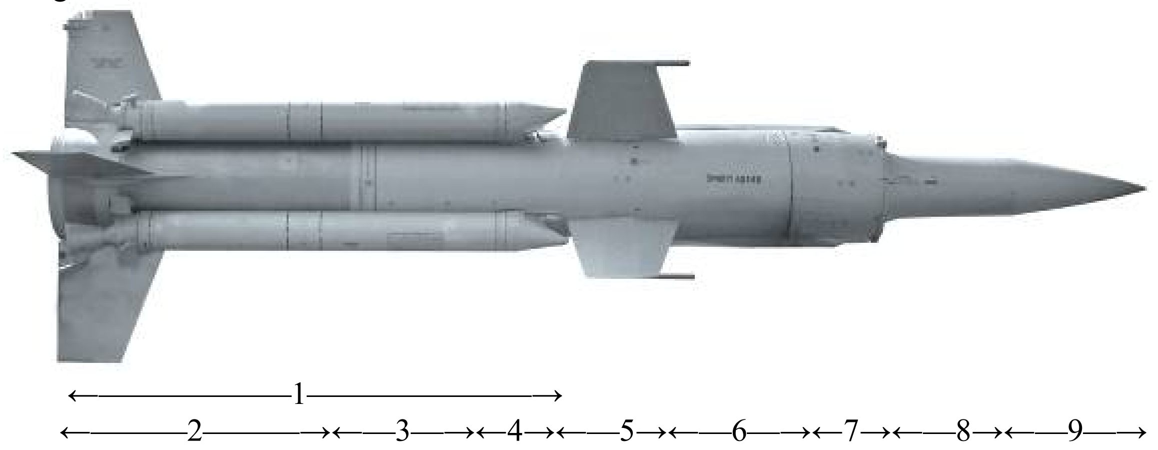


1, By switching the PI switch to the upper position, the SNR transfers to the Periodical Illumination Target Tracking Mode.

2, When the SNR is off the air, it is safe from the enemy’s Anti-Radiation Missiles, the “ИЗЛУЧЕНИЕ ВЫКЛЮЧЕНА” (Radiation Off) indication is illuminated.

3M8 (Ganef Mod.0) surface to air missile

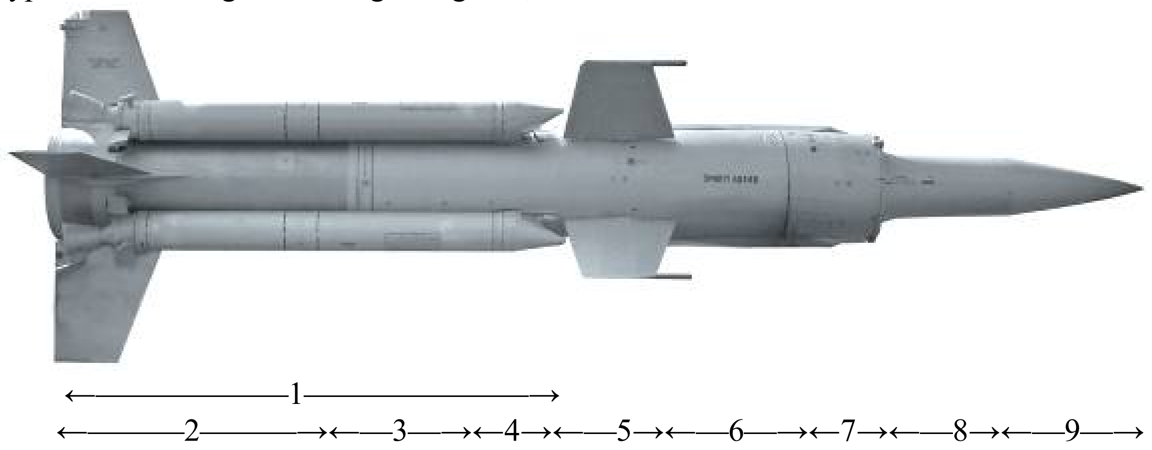
Fielded from 1964, the first missile type of the KRUG system. Launch weight: 2’452kg. Length: 8,436m.



1. **4pcs 3C5 solid fuel booster.**
   Propellant: 4L12M nitrocellulose tube (outer/inner Ø: 28,2/8,5cm, length: 2,635m)
   Propellant/launch weight: 173/273kg
   Burn time: 4s
2. **3C4 ramjet sustainer.**
   Maximum thrust: 769,3kN
   Burn time: 65s
   Range (min/max): 11-45 km
   Altitude (min/max): 3’000-23’500m
   Max. overload: 4g (between 0-12’000m altitude, than linearly decreasing till 0g)
3. **OT-155 „Isopropyl-nitrate” tank**
   Weight: 22kg
   Composition: $C_3H_7NO_3$
4. **1SB5 autopilot.**
5. **Steering fins**
6. **T-1 „Kerosene” fuel tank.**
   Weight: 275kg
7. **3E26 radio proximity fuse**
8. **3N11 warhead.**
   Weight: 150kg
9. **Radome**

3M8M1 (Ganef Mod.0) surface to air missile

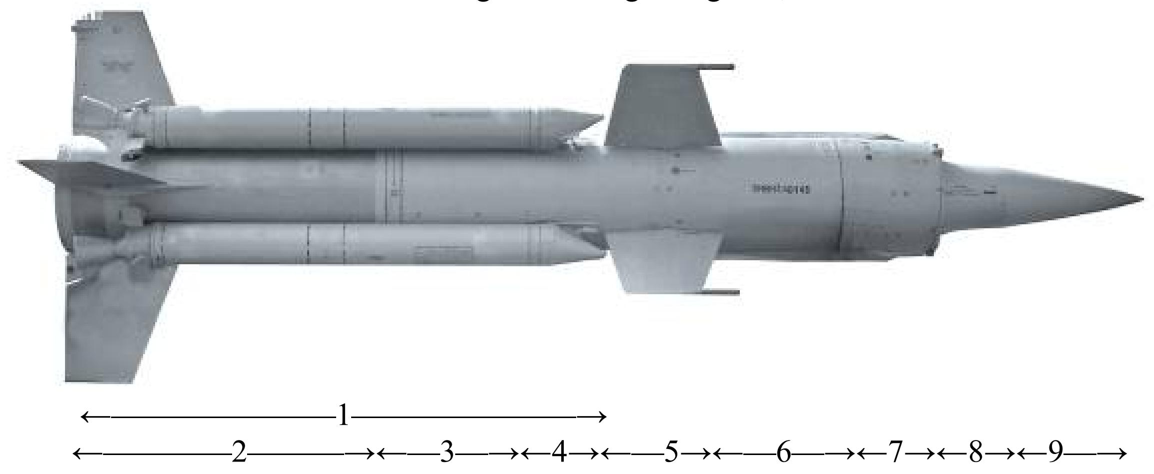
Fielded from 1967, the extended maximum range, and reduced effective altitude second type. Launch weight: 2’459kg. Length: 8,436m.



1. **4pcs 3C5M solid fuel booster.**
   Propellant: 4L12M2 nitrocellulose tube (outer/inner Ø: 28,8/8,5cm, length: 2,635m)
   Propellant/launch weight: 173/274kg
   Burn time: 4s
2. **3C4M1 ramjet sustainer.**
   Maximum thrust: 982kN
   Burn time: 72s
   Range (min/max): 9-50 km
   Altitude (min/max): 250-23’500m
   Max. overload: 5g (between 0-12’000m altitude, than linearly decreasing till 0g)
3. **OT-155 „Isopropyl-nitrate” tank**
   Weight: 22kg
   Composition: $C_3H_7NO_3$
4. **1SB5 autopilot.**
5. **Steering fins**
6. **T-1 „Kerosene” fuel tank.**
   Weight: 275kg
7. **3E26 radio proximity fuse**
   Minimum target altitude: 250m
8. **3N11 warhead.**
   Weight: 150kg
9. **Radome**

3M8M2 (Ganef Mod.1) surface to air missile

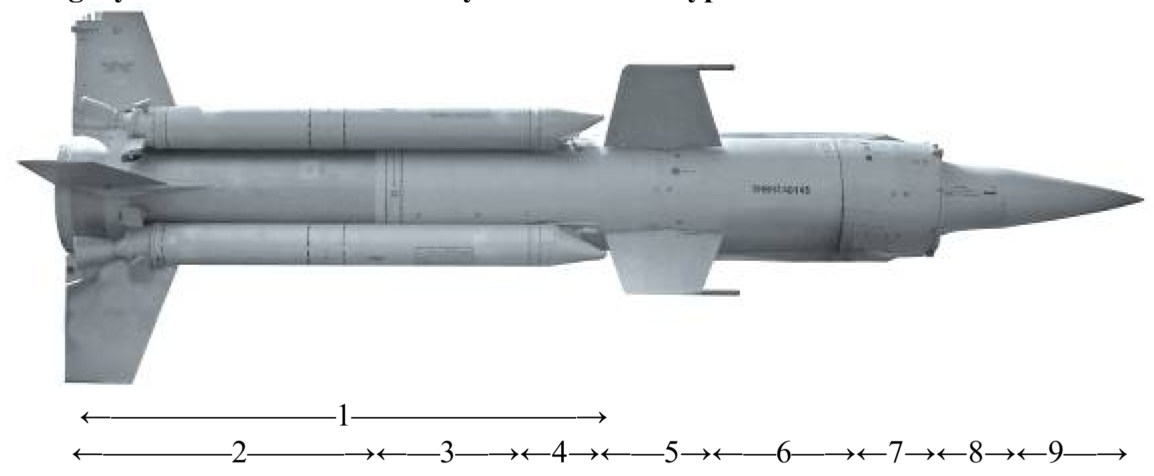
Fielded from 1971, the first short nosed version had extended maximum altitude, and more effective warhead. Launch weight: 2’453kg. Length: 7,842m.



1. **4db 3C5M solid fuel booster.**
   Propellant: 4L12M2 nitrocellulose tube (outer/inner Ø: 28,8/8,5cm, length: 2,635m)
   Propellant/launch weight: 173/274kg
   Burn time: 4s
2. **3C4M1 ramjet sustainer.**
   Maximum thrust: 982kN
   Burn time: 72s
   Range (min/max): 9-50 km
   Altitude (min/max): 250-24’500m
   Max. overload: 5g (between 0-12’000m altitude, than linearly decreasing till 0g)
3. **OT-155 „Isopropyl-nitrate” tank**
   Weight: 22kg
   Composition: $C_3H_7NO_3$
4. **1SzB5M2 autopilot.**
   Maximum flight time: 80s
5. **Steering fins**
6. **T-1 „Kerosene” fuel tank.**
   Weight: 275kg
7. **3E26M2 radio proximity fuse**
   Minimum target altitude: 250m
8. **3N11M warhead.**
   Weight: 150kg
   Number of fragments / weight: 15’000pcs / 4g
   Type of explosive / weight: TG-20 / 90kg
9. **Radome**

3M8M3 (Ganef Mod.1) surface to air missile

Fielded in 1974, the second short nosed version was capable of destructing receding targets, had reduced preparation time before launch, extended minimum altitude/range, and increased maneuverability. Launch weight: 2'453kg. Length: 7,842m.
Hungary fielded the KRUG-M1 system with this type of missile in 1982.



1. **4pcs 3C5M solid fuel booster.**
   Propellant: 4L12M2 nitrocellulose tube (outer/inner Ø: 28,8/8,5cm, length: 2,635m)
   Propellant/launch weight: 173/274kg
   Burn time: 4s
2. **3C4M2 ramjet sustainer.**
   Maximum thrust: 982kN
   Burn time: 72s
   Range (min/max): 6-50 km
   Altitude (min/max): 150-24'500m
   Max. overload: 6g (in the entire flight envelope)
3. **OT-155 „Isopropyl-nitrate" tank**
   Weight: 22kg
   Composition: $C_3H_7NO_3$
4. **1SzB5M3 autopilot.**
   Maximum flight time: 80s
   Time to spin up gyroscopes before launch: 35 s
5. **Steering fins**
6. **T-1 „Kerosene" fuel tank.**
   Weight: 275kg
7. **3E26M3 radio proximity fuse**
   Minimum target altitude: 150m
8. **3N11M warhead.**
   Weight: 150kg
   Number of fragments / weight: 15'000pcs / 4g
   Type of explosive / weight: TG-20 / 90kg
9. **Radome**

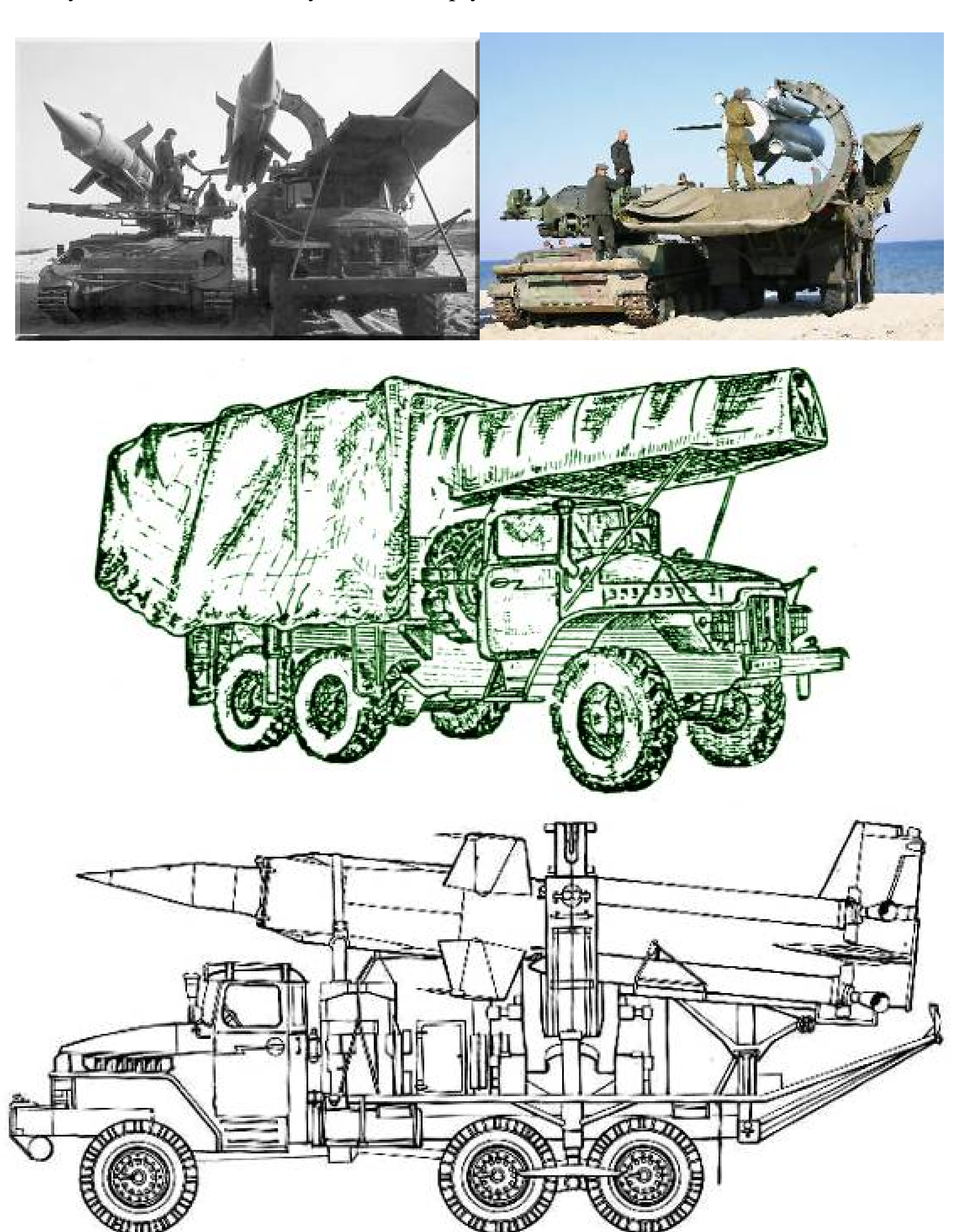
2P24M1 SPU mobile launcher

The KRUG battery has three self propelled, NBC (Nuclear Biological Chemical) protected (by filtered over-pressurization system) launchers, with two missiles per launcher.



2T6M TZM missile loader

The TZM is an URAL-375E truck with an inbuilt crane.
The reload of the missiles from the missile transporter (TM) to the launcher (SPU) is done by the TZM. The battery has one empty TZM vehicle.



9T25 or 9T226 TM missile transporter

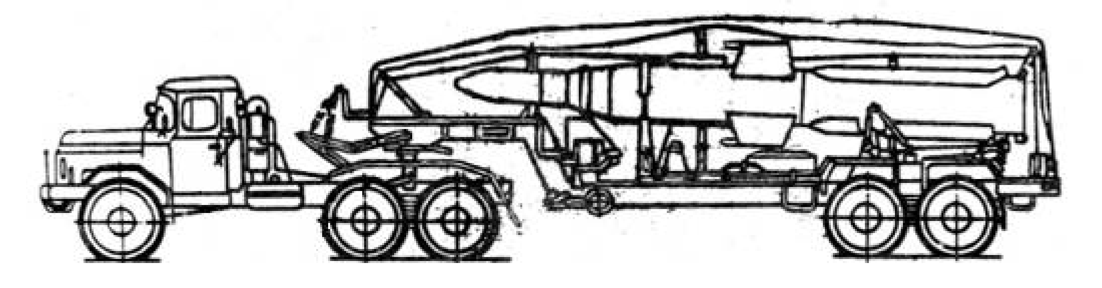
The TM is a PUA-3 missile transporter-loader semi-trailer, towed by a ZIL-157 (in case of 9T25 TM) or a ZIL-131 (in case of 9T226 TM) truck. The missile is reloaded from the TM (missile transporter) to the SPU (self propelled launcher) by the TZM (missile loader). Each battery has 3 TM vehicles, to store a total of 3 extra missiles.

(9T25 TM)



(9T226 TM)



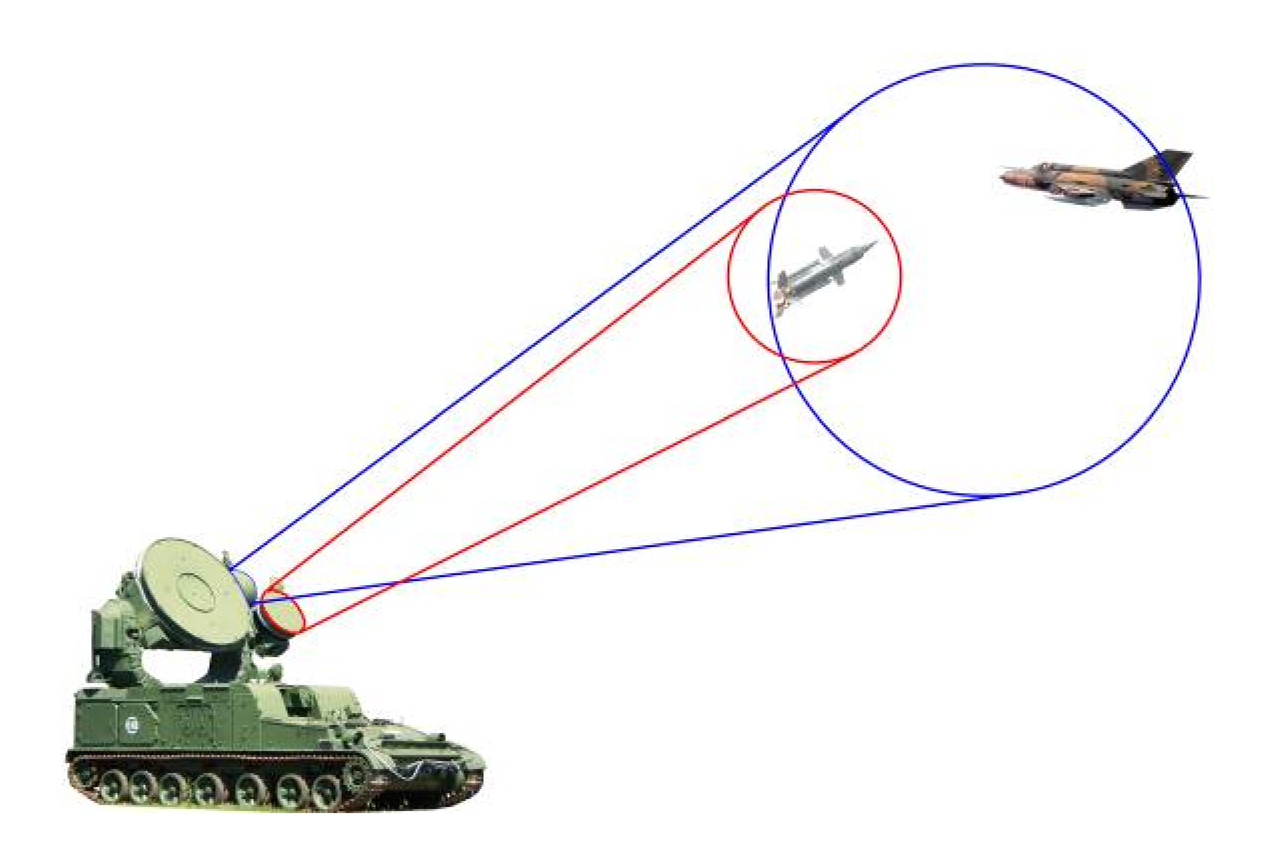


Missile guidance

The missile doesn't "see" the target, it flies by remote control.

The AVS-II antenna system (red) is passively tracking the missile's beacon.
The SPK antenna (blue) (fixed on the AVS-II missile tracking tower) is transmits the missile guidance signal commands (K1, K2, K6, and K9).

K1, K2 guidance signal (missile rudder angle command)
K6 fragments dispersion configuration command (depending on the speed of target)
K9 radio proximity fuse arming command



Observing the tracked target's flight parameters using the DHV instrument

The targets flight parameters can be observed on the combined DHV instrument.
(Push the "X" button to call up the Angle Officer's K11-102M1 panel)



1, leaving the DHV instruments selector switch in the middle position, the instrument is displaying the target's distance, in the 0-100km range (0km at left, 100km at right). Current indicated target distance is 60km.

2, setting the DHV instruments selector switch to the lower position (by clicking on it with the left mouse button), the instrument is displaying the target's altitude, in the 0-25km height range (0km at left, 25km height at right). Current indicated target height is 4km.

3, setting the DHV instruments selector switch to the upper position (by clicking on it with the right mouse button), the instrument is displaying the target's altitude, in the 0-5km height range (0km at left, 5km height at right). Current indicated target height is 4km.



4, pushing the DHV instruments Vr button (by clicking on it with the mouse button, and keeping it pushed down), the instrument is displaying the target's speed, in the 0-1000m/s range (0m/s at left, 1000m/s height at right). Current indicated target speed is 80m/s.

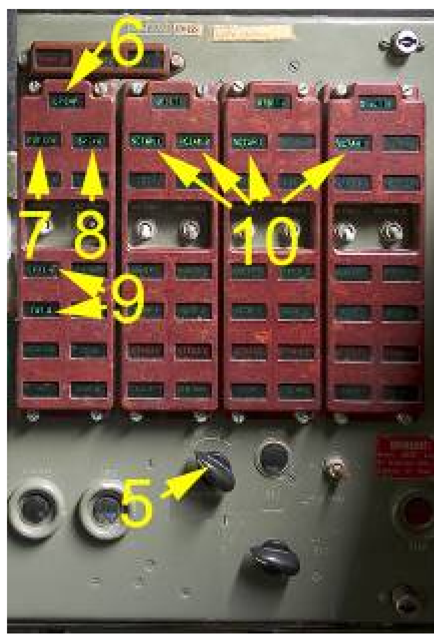
Preparation of the 3M8M3 (Ganef Mod.1) missile

The preparation state of the battery’s 6 missiles can be followed on the Commander’s K04-1M1 panel.

(Push the “X” button to call up the Commander’s K04-1M1 panel)

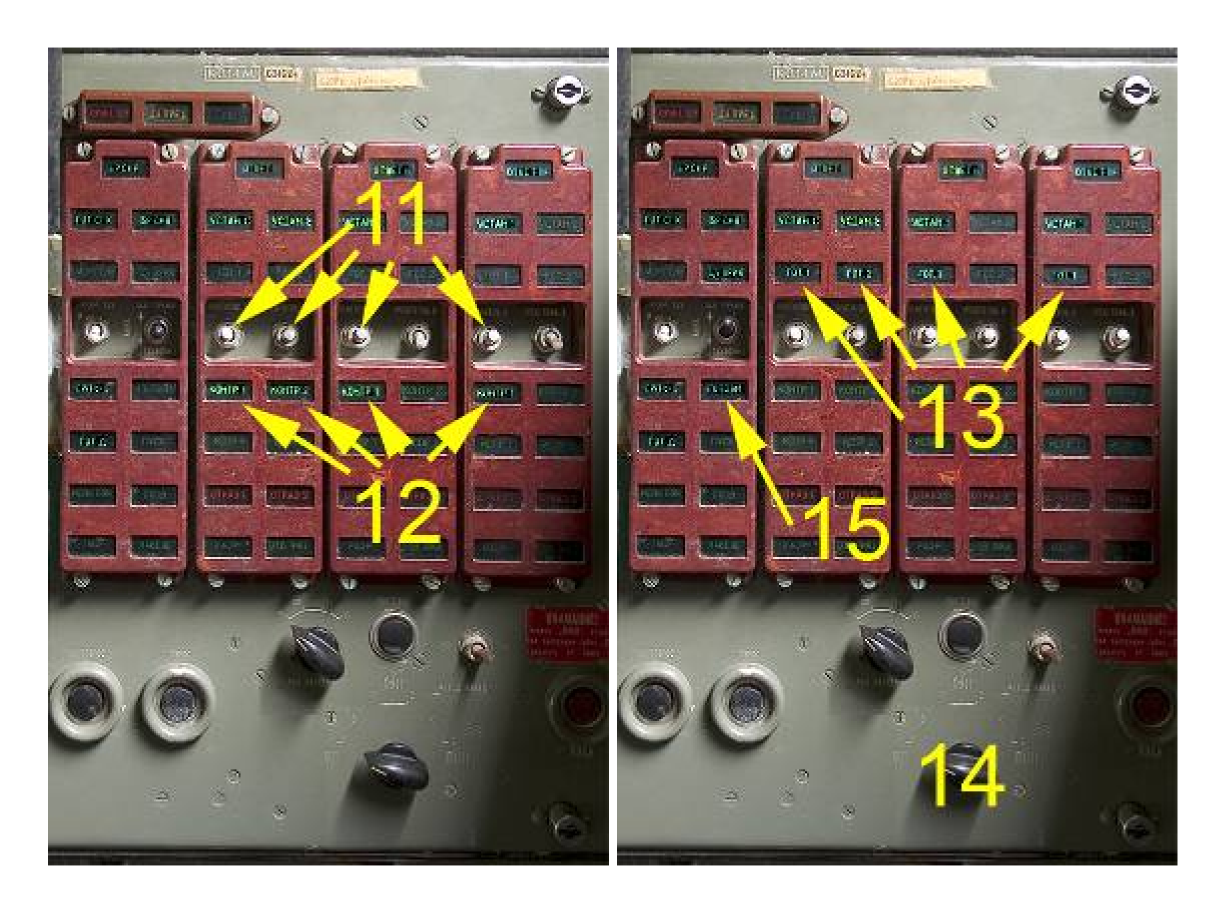


Columns
The four columns displays the four fighting element of the KRUG system. The leftmost column is for the SNR. The other three are for the launchers in terms of their direction from the SNR I Southwest (1), II North (2), III Southeast (3).
The “**ОТВЕТ I, II, III**” indications at the top of the columns are showing, that the SPU’s (self propelled launchers) are successfully logged on to the 1S63 digital wireless data network.
4, The “**ОТВ. ФК I, II, III**” indication shows that the SPU’s are in practice mode.



5, Clicking on the mode selector switch, we select the “**БР**” live fire mode (left) instead of the “**ФК**” practice mode (right).
6, “**БР СНР**” indication shows, that the SNR (fire control radar) is in live fire mode.
7, “**ГОТ. СПК**” indication shows, that the SPK (missile guidance system) is ready for live fire.
8, “**БР СРП**” indication shows, that the SRP (analogue computer) is ready for live fire.
9, “**СРП t=0**”, and “**ГОТ. Д**” indication shows, that the SRP (analogue computer) is ready for live fire.
10, “**УСТАН. 1, 2**” indication shows, that missile is loaded onto the launcher.

Note, that the SPU-I has two missiles loaded, while the other two has one. (altogether four)



11, Switching the “**ПОДГОТОВ. 1, 2**” switches up, we command the loaded missiles, to spin up the gyros.
12, “**КОНТР. 1, 2**” indication shows, that the missile’s is under preparation.
13, When the missile’s gyros were spun up to nominal speed, the “**ГОТ. 1, 2**” indicator will shows that the missile is ready for launch.
14, By rotating the missile selector switch, we can select one of the missile for launch.
15, “**ГОТОВН.**” Indication shows, that the selected missile, is ready for launch.

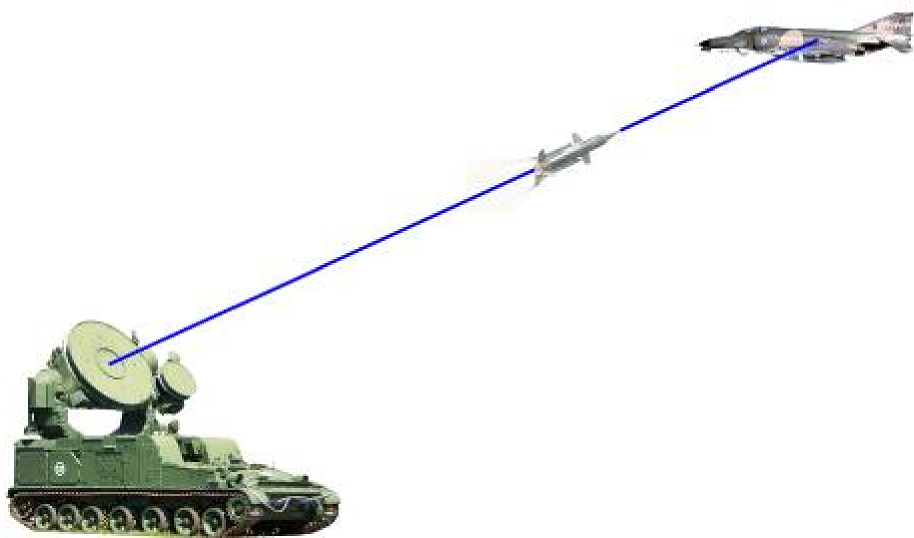
Selecting missile guidance method

Preparations for Shooting using ”3m” (Three Point) guidance method

(Push the “X” button to call up the Commander’s and Angle Officer’s panels)

If the target parameters are in the green zone, (H 300m-16km, V<=330m/s) the “three-point” guidance method is selected.

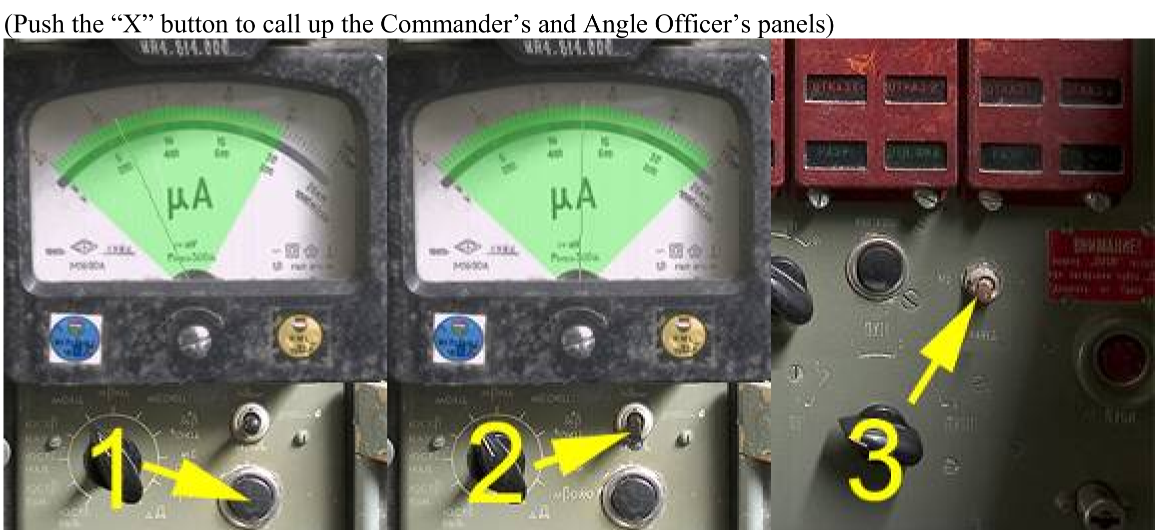
1, pushing the Vr button (by clicking on it with the mouse button, and keeping it pushed down), the DHV instrument is displaying the target’s speed.
2, setting the selector switch to the lower position (by clicking on it with the left mouse button), the DHV instrument is displaying the target’s altitude.
3, “**3m**” (Three Point) guidance method is selected by the right position of the “**МЕТОД НАВЕД**” switch.



Three-point guidance gets its name from the fact that the radar, missile and target are always lined up like three points on a straight line. In this mode the missile is always flying directly at the target.

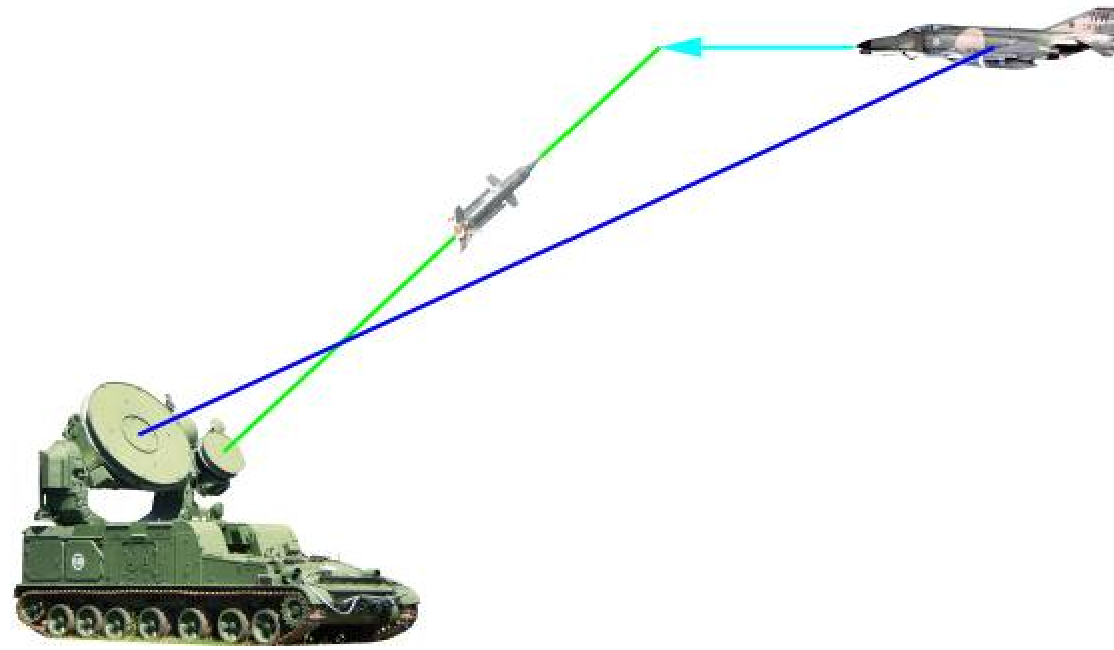
Preparations for Shooting using "½" (Half-Lead) guidance method

(Push the "X" button to call up the Commander's and Angle Officer's panels)



If the target parameters are in the green zone, (H 300m-24.5km, V<=800m/s) the "half-lead" guidance method can be selected.

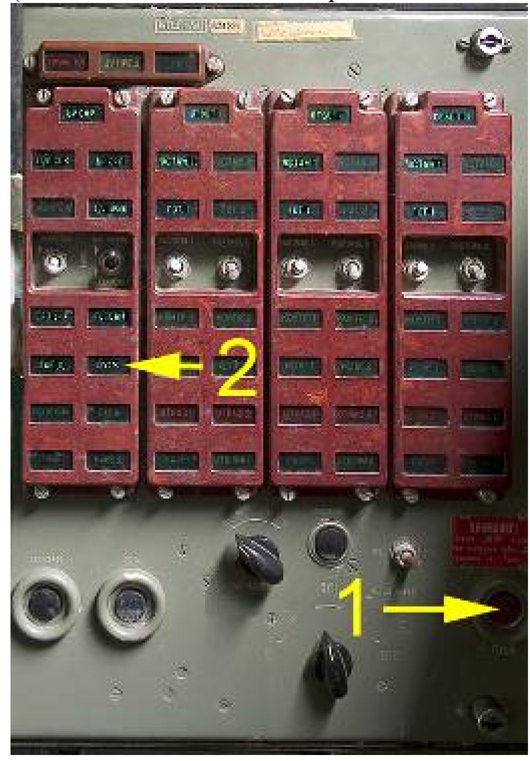
1, pushing the Vr button (by clicking on it with the mouse button, and keeping it pushed down), the DHV instrument is displaying the target's speed.
2, setting the selector switch to the lower position (by clicking on it with the left mouse button), the DHV instrument is displaying the target's altitude.
3, "½" (Half-Lead) guidance method is selected by the left position of the "**МЕТОД НАВЕД**" switch.



Using this guidance method, the missile is flying to pre-calculated impact point.

Ну Давай! ПУСК!

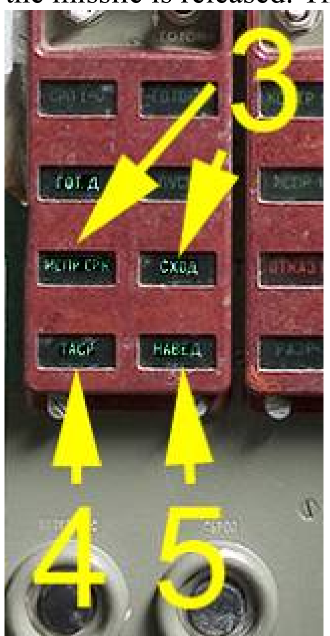
(Push the “X” button to call up the Commander’s K04-1M1 panel)



1, If the target is inside the launch envelope, the missile can be launched with the “**ПУСК**” button.
Note, that this is the first eastern SAM system, where the launch button is really red, as in the movies. ☺

2, After pushing the launch button, the launch command goes through the 1S63 digital wireless data network to the selected SPU (mobile launcher). When the command is acknowledged, the “**ПУСК**” indication is illuminated.

First, the cover of the air intake is ejected, and then the pyrotechnical switch opens the pressurized air valve. Pressurized air is required for the launch sequence, and during the flight, for operating the steering fins. It pushes up the electrolyte from the plastic bags into the battery cell. After a fraction of a second, the battery is capable of providing full power. When the onboard power supply was ready, the solid fuel booster is ignited. As the SPU (launcher) has no launch rail for the missile, it holds it firmly, until the solid boosters reach full thrust. When it happens, the missile is released. This sequence is completed within ~2sec.



3, When the missile is released by the launcher, the “**СХОД**” indication will illuminate, and the command guidance signals started to be transmitting indicated by the “**ИСПР. СПК**” sign.

After 4 second of acceleration, the missile is flying over Mach1.8, and the solid boosters are ejected. The ramjet engine is started, and the onboard beacon starts transmitting.

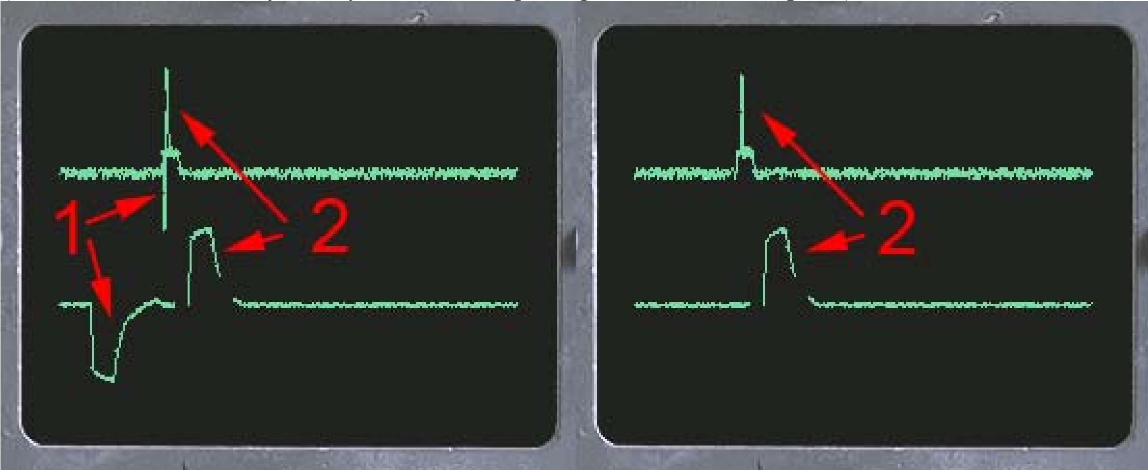
4, After the AVS-II wide beam missile tracking antenna captures the missiles beacon, the missile tracking tower starts the tracking of it with the narrow beam antenna, and the “**ТАСР**” indication comes up.

5, If the missile’s guidance method is three-point, the AVS-I target tracker system is tracking the missile, instead of the AVS-II, and it is indicated by the “**НАВЕД**” light.

Observing the result of the shooting

Several factors are needed to be observed, to assess the result of shooting:

(Press the “Z” button on your keyboard to call up Range Officer’s K81-8 panel)



The missile’s negative spike (1) disappears after reaching the target’s positive spike (2).

(Push the “X” button to call up the Angle Officer’s K11-102M1 panel)

The height (3) and speed (4) of the target decreases.

3, setting the DHV instruments selector switch to the lower position (by clicking on it with the left mouse button), the instrument is displaying the target’s altitude.
4, pushing the DHV instruments Vr button (by clicking on it with the mouse button, and keeping it pushed down), the instrument is displaying the target’s speed.

Resetting the tracking systems

(Push the “X” button to call up the Commander’s K04-1M1 panel)



The Battery Commander can reset the two tracking systems, the AVS-I (target tracking system), and the AVS-II (missile tracking system) with two method.

1, By pushing the “**ПОЛУСБРОС**” (half reset) button, only the AVS-II (missile tracking system) is reset, the AVS-I (target tracking system) continues to track the target.

This is used if the first missile missed the target, and another missile is planned to be launched against the same target.

2, By pushing the “**СБРОС**” (full reset) button, both AVS-I/II (target/missile tracking system) is resetted.

This is used if the missile hit the target, and another target is to be tracked.

3, By switching the „**ИЗМ. ЦУ**” (request new target designation) switch to up, we request new target designation from the 1S12M1 SOC radar. When the target designator line appears at the SOC indicator, the switch can be switched down.

Electronic warfare

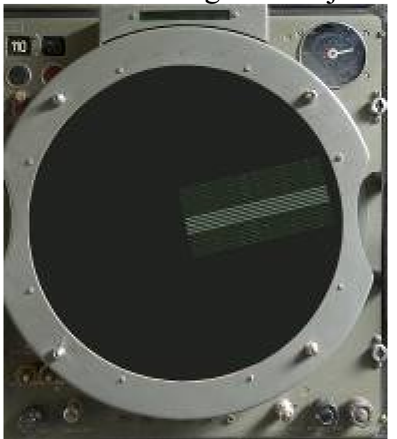
Noise jamming



Noise jamming pods, used since the middle of 60’s, are suppressing the radar echo of the carrier aircraft with strong noise, denying the range information from the fire control radar.

Decimeter wavelength noise jamming, centimeter wavelength noise jamming





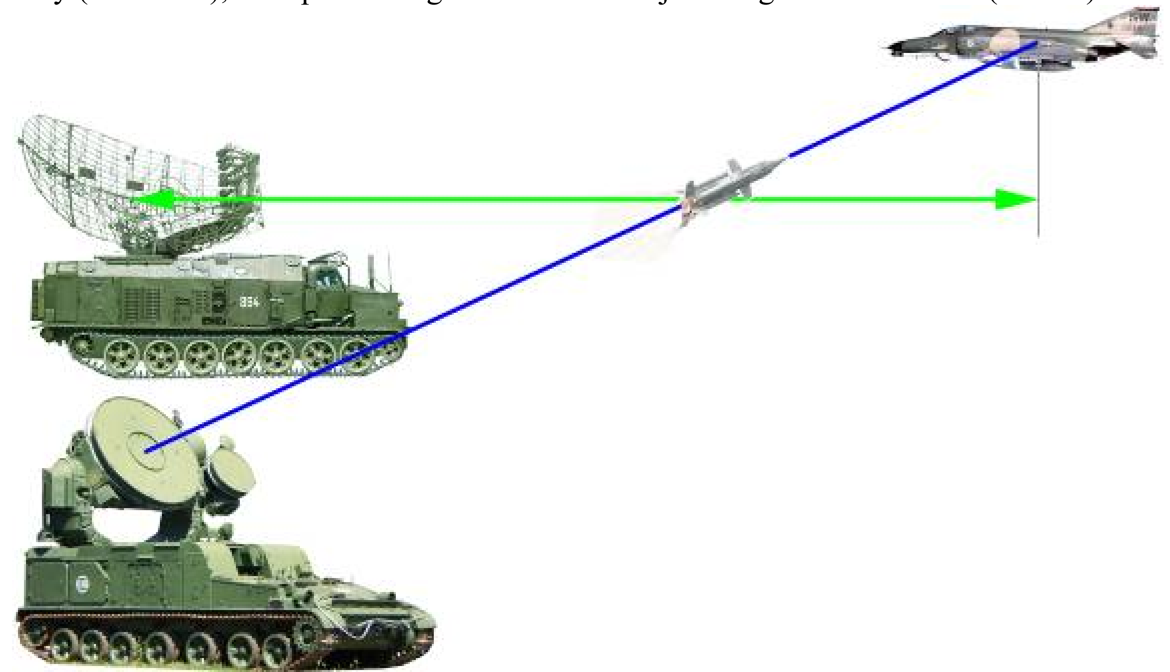
The noise jamming target is creating a band in the indicators. The jamming target could be acquired in elevation and azimuth, but not in range.

1, Note, that by using AGC (Automatic Gain Control) the 1S12M1 SOC (Long Track) Target Designator Radar can track the jamming targets azimuth precisely.

Preparations for Shooting at Noise Jamming Targets

Missile guidance with “3m” (Three-Point) method

Shooting against noise jamming targets, the “**3m**” (Three Point) missile guidance method is used, where the missile is aimed towards the jamming target all the time.
Target range is continuously calculated, using the measured **elevation**, and manually input **distance** from the 1S12M1 SOC radar in case the target is jamming on the cm band only (C- button), or expected target **altitude** if the jamming is on both band (cm/dm).



Shooting on noise jamming target

(Press the “Z” button on your keyboard to call up Range Officer’s K81-10M panel)

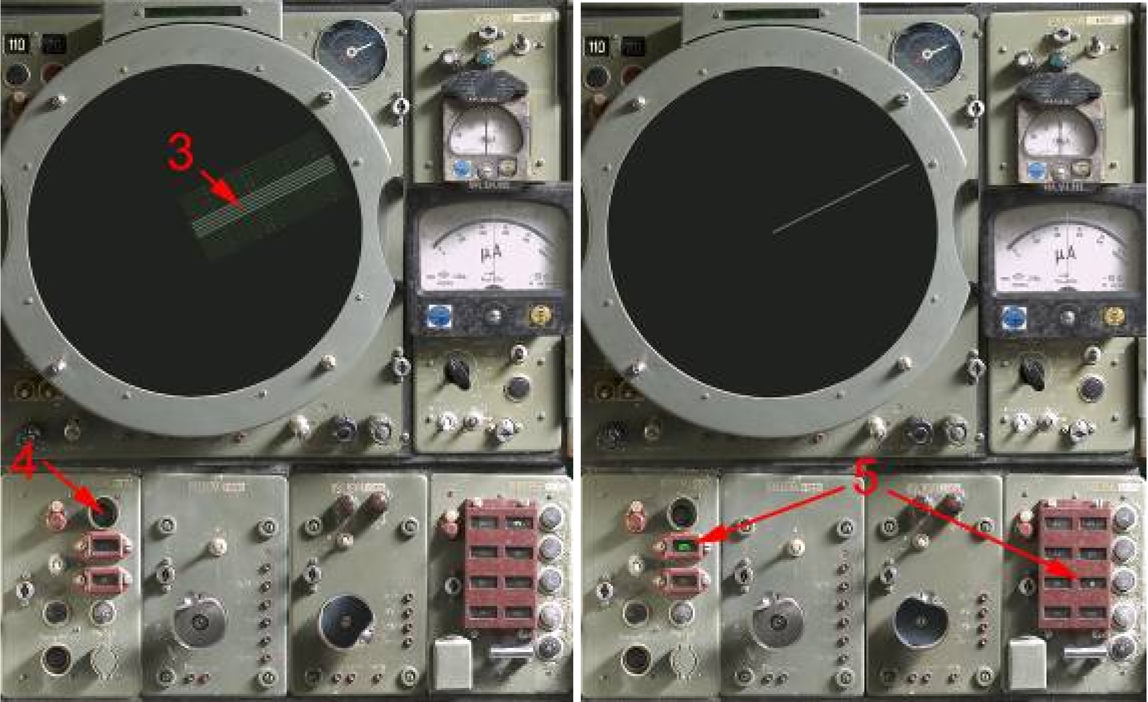


(Press the “X” button on your keyboard to call up Battery Commander’s K94-2M1 panel)



Tracking of noise jamming targets could be done in passive mode, where the antenna receiver is open (1), but the transmitter is turned off (2).
Because the radar is not emitting it cannot be detected by electronic countermeasures and SIGINT receivers.

(Push the “X” button to call up the Angle Officer’s panels)



When the noise band is touching the bore sight (3), the RPC (target tracking system) could be switched into the “**АСЦ**“ (Automatic Angle Tracking) mode, by clicking on the ASC button (4). If the transition was successful, the “**АСЦ** “, and the “**П**” (5) indicator will illuminates. From now, the AVS-I (RPC) system is automatically angle tracking the jamming target.

(Press the “Z” button on your keyboard to call up Range Officer’s panels)



6, As the target radar echo is suppressed by the noise jamming, it cannot be range tracked.

7, “**ПА**” (Manual Range Tracking) mode is selected by clicking on the PA button.

8, By switching the missile fuse arming selector to up “**Ш. П.**”, the fuse will arm right after launch.

9, Holding down the left mouse button over the wheel, and pressing “X” on the keyboard, we can manually set the target distance, or altitude into the DHV instrument, by moving the mouse right-left.

Now the calculated distance of the jamming target is shown, it could be engaged as if it would be a normal target.

(Push the "X" button to call up Angle Officer's K81-5A panel)

